FISHES

THEIR WAYS OF LIFE

By LOUIS ROULE

Author of

"FISHES: THEIR JOURNEYS AND MIGRATIONS"

FISHES

Their Ways of Life

The scientific competence of the author in the domain of ichthyology is unimpeachable. But he further possesses a gift of imaginative insight which is unparalleled in the subject he has made his own. If ever an author made the dry bones of a science live, he does.

In the present volume, Professor Roule sets out to show the amazing diversity of the activities displayed by the denizens of what he calls "the living world of the waters". To us who live in a completely different medium, he opens up a vista of astonishing interest, beauty, and variety. As the author makes clear to us, the life he describes has preserved more closely the essential and original qualities of all life.

Professor Roule, as usual, seems to cover a very wide range, though his studies are closely related. He discusses the different ways in which fishes swim; describes the odd ingredients which go to make up the world-famous *Bouillabaisse*; then turns to such fascinating subjects as shark's teeth, poisonous fish, electric fish.

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THEIR JOURNEYS AND MIGRATIONS

"Professor Roule is a learned zoologist, but also an artist in description, and his story of the trout and the salmon, the herring, sardine, and tunny, the eel, and other fishes, is good reading for its own sake, either to fishermen or to a more general public. It is full of information, exact and curious. But the book has a higher purpose and a greater value. . . ."

—*Times Literary Supplement.*

FISHES
THEIR WAYS OF LIFE

BY

LOUIS ROULE

Professor at the National Museum of Natural History in Paris
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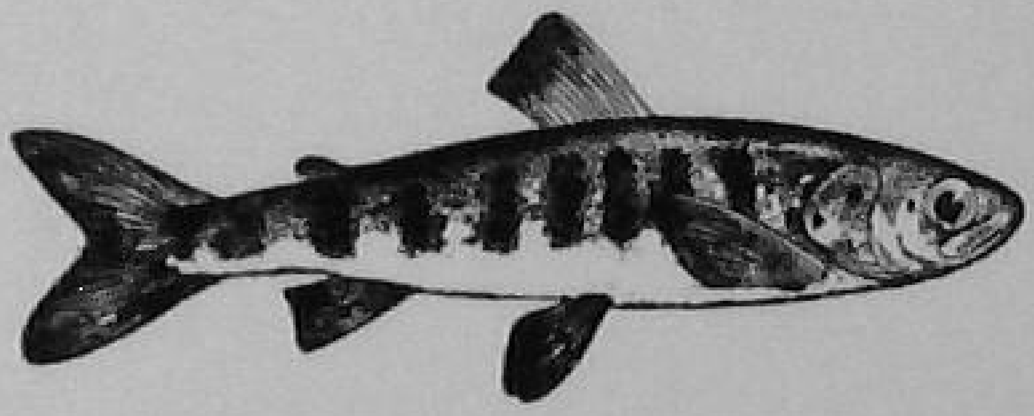
TRANSLATED FROM THE FRENCH BY

CONRAD ELPHINSTONE



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FISHES
Their Ways of Life

CHAPTER I

THE TEEMING LIFE OF THE WATERS

Many keen fishermen have a particular devotion to that form of the art which is practised from a boat, and among their number I certainly include myself. I have often practised their art in the past, and I practise it still. At any fit and proper time I am prepared to accompany a friend to river, lake, or sea, especially the sea. And so I find delights unknown to the shore fisherman. I am brought closer to creatures which must be watched for if they are to be caught, and I have a greater share in their existence. Fishing is no longer a sedate and tranquil form of recreation, no longer a mere stroll along a river bank, or an excuse for a nap; it becomes something more in the nature of hunting, of the chase. It has attractions and dangers all its own.

But I do not always confine myself to that common type of fishing which is concerned with catching fish and nothing more. I am after something more than this, and I use special gear. As a naturalist I fish because I seek to garner all the living creatures that dwell in the waters so that I may know them all and learn all about them. The world of waters does not consist only of the fish we use for food. Together with these live other creatures having a place and usefulness of their own. And they are all worth knowing. So,

besides fitting myself out with rods, lines, gaffs and strong landing nets, I take with me several curious-looking pieces of gear, a little drag, for instance, to scrape the bottom and gather up the animals which live there, and a silk bag-net in which to collect those which float.

This bag-net is the most distinctive part of my naturalist's equipment. It is commonly known as a "plankton net" from the term commonly employed in all languages to denote all those creatures which live suspended in the water and are borne along by it. It is a sort of long narrow bag, made of strong silk, fine enough to let the water filter through its meshes yet imprisoning even the tiniest of tiny creatures. The open front part of this bag is attached to a rigid frame which keeps it open and it gradually narrows down to an orifice into which a glass bowl fits exactly. After being completely submerged in the upper levels of the water, it is made fast to the stern of the boat, and slowly drawn along by keeping the boat slowly and regularly moving. If we lean over the side, we may see it swell and distend under the pressure of the water which forces its way into it, and the tiny creatures which float in that water are collected in the bowl at its bottom. When our day's fishing is done we find them there.

I have many pleasant memories of such open water trawling, and in them I re-live many a delightful hour. It is hard to recall any experiences so completely satisfying as those met with on the sea, with the clear sky above, on some calm peaceful summer morning, after a stifling night spent beneath a roof. The heart seems to grow perceptibly lighter; care vanishes into thin air; one acquires new vigour; and the physical sense of well-being opens up new possibilities of spiritual joy. And though every such morning is lovely and delightful, no two of them are alike. Each has a charm and a joy peculiar to itself.

At dawn we set out, and the last belated stars are still shining in the sky. It is a real pleasure to savour the sharp, salty, slightly iodized smell given off by the whole surface of the sea. It is cool and refreshing. We hear the gentle murmur of the surf caressing the rocky shore. Up with the anchor and out to sea! Sometimes the sea is perfectly calm, untroubled by the slightest ripple; the boat seems to glide over it. Sometimes it rises, slowly, gradually, regularly, in a broad, waving swell, a strong swell that keeps the boat swinging in ceaseless rhythm; it seems to quiver, and, with its rocking, to communicate that quivering to the boat. Sometimes it is different again. Always like to itself in the immensity of its mass, its aspect differs from moment to moment and from place to place.

One day, the sky is serene and cloudless. Dawn breaks, the light grows stronger, and the sun comes up, never pausing, never halting. Every conceivable shade of gold and blue is reproduced in the sparkling waters. The distant cliffs merge into the hills beyond, and with them form a pale blue battlemented wall in which it is impossible to distinguish any particular point because the glowing light absorbs all detail. Another day, the sky is grey, covered by clouds which hide the sun; there is a soft, uniform light which seems as though it had been filtered through a sieve; everywhere the sea is grey, greenish, and leaden, with flickers of blue-green and silver. The distances stand out, dark blue, and every fold in the ground is to be seen. Little by little, as the morning hours pass, the clouds disperse, letting the sun through. At first, broad straight bands of light, spread like a fan, descend upon the water from the heavens, bringing a bright sparkle. Then the light brightens; the sun appears; the clouds vanish, and the clear sky covers land and sea in one vast dome. One scene from Fairyland after another, a sparkling and blazing which gives an element

of the miraculous to our activity, and makes the ragged fisherman who stands upright in his boat some distance away, a glorious being, illuminate, superhuman, with a halo of purple and gold about his head.

Some distance from the shore, where its influence and that of its waters are unfelt, I lean over the side and examine the pure deep water that alone surrounds me. It is perfectly transparent, with a limpidity which even the clearest fresh water can never attain. When I plunge my hand into it, I can distinguish every fold in the skin even more clearly than I can in the air. Nothing seems to disturb its purity. Yet, if I put out my plankton net and trail it for a few moments, then pull it out of the water to see what is in the glass bowl, I find a host of minute bodies in suspension, some motionless, some active, all clearly to be seen against the light. They are a proof that the sea, though it seems so pure, harbours multitudes of living beings. These creatures, mostly transparent and with hardly a suggestion of colour, are scattered and comparatively few, so that when we look at the water from the boat they do not affect its clearness. But when they are caught in the net, and collected in the little bowl, they are much more easy to see than when scattered, as they usually are, over a much greater area. Some, which are fairly large, measure several millimetres. But there are smaller ones which are difficult to see, larvæ or other tiny little animals. Some of them, the most numerous, are infusoria and unicellular algæ, and these we shall only discover with the help of a microscope in our laboratory.

Sometimes this astonishing world suspended in the water reveals itself more clearly. This happens when the sea, ceaselessly stirred by streams and currents interlacing in all directions, gathers in some of these currents the creatures it maintains. Then, more numerous than in other places, they increase rapidly and accumulate. Their quantity affects the purity of

the water, which becomes cloudy and assumes the hue of the most abundant. Fishermen know the currents thus laden. According to their appearance they call them "thick" waters, or green waters, or blue waters. They are recognised as the promise of an excellent catch, for they contain a great number of fish which settle there and gorge themselves on the abundant accumulation of these little creatures held in suspension. Usually these currents are found only in deep water, as though the shore kept them at a distance; but, sometimes, they approach the coast for a while, and then they offer of their abundance to the fishermen, who are not slow to profit by the opportunity.

Naturalists, after realising the existence of this floating world, have measured it with a view to discovering its capacity. The huge figures resulting from their calculations resemble those obtained by astronomers in the stellar world. The infinitely great and the infinitely small here are alike. It has been calculated that a cubic centimetre of sea water may contain several dozens, even several hundreds, of these microscopic beings. When we think of the enormous number of cubic centimetres in the ocean the figures become almost staggering. A specialist in this subject found that a portion of the Baltic Sea, measuring superficially a quarter of a square mile, and about sixty-five feet deep, contains a hundred thousand million small crustacea of the group of Copepods, whose total weight amounts to more than 190 tons. In the North Sea, the same naturalist found that for every square metre of surface, the water contains a mass of microscopic algæ, of the order of Diatoms, occupying in all 6570 c.c. and representing thousands of millions of individuals. These Diatoms, held in suspension in the water, serve as food for the Copepods which float like themselves, and these, in their turn, serve as food for the little species of fish which swim among them. The quantity of organic substance represented

by the total of successive generations of these Diatoms and Copepods is equivalent to nearly 150 grammes per square metre of the sea's surface. None of our well-cultivated fields, area for area, could do more.

This extraordinary world has been given a name: the word "plankton" has been created especially for it, and this term is now universally used. But it only expresses a part of the reality. Impressed by the way these floating beings are carried about by the currents, thus forming an immense mass of wandering individuals

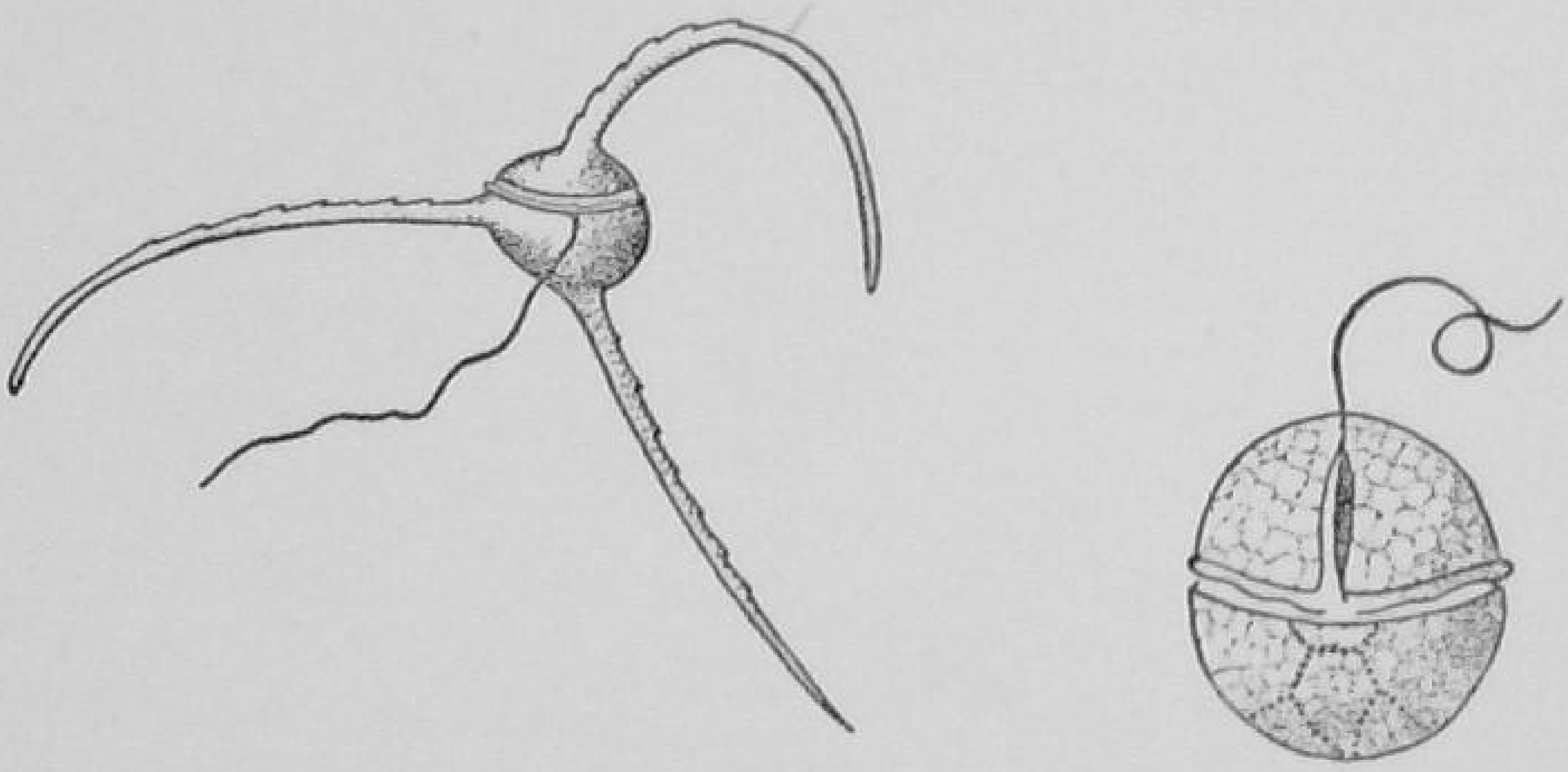

FIG. 1.—Common Dinoflagellates of the plankton. Left, a *Ceratium*; right, a *Peridinium*. These creatures, which exist in great numbers and are invisible to the naked eye, are very tiny, varying according to species, from $\frac{1}{10}$ to $\frac{1}{30}$ of a millimetre.

without any fixed home, the author of the name, the oceanographer Hensen, expressed that state by the word plankton, which is related etymologically to "planets", stars which wander about the heavens. But this name does not take into account the principal characteristic. It forgets the strange, preponderating quality which these creatures possess of floating continually, remaining suspended in the water for their whole existence, from birth to death, never settling and never resting, a characteristic which is unique, which makes of this plankton a strange living assemblage with no corresponding equivalent in life on land.

If I turn over the pages of my old notebooks and sketchbooks I find the shapes and forms of these creatures for which I have often fished, though fishermen of the usual type know nothing of them. I discover impressions, remarks, like those of other naturalists who like myself have fished for the same catch. These planktonic creatures belong to many of the groups of marine life. Animal and vegetable kingdoms are represented in them, though unequally, for animals predominate as regards mass, diversity, and complexity, often by size too.

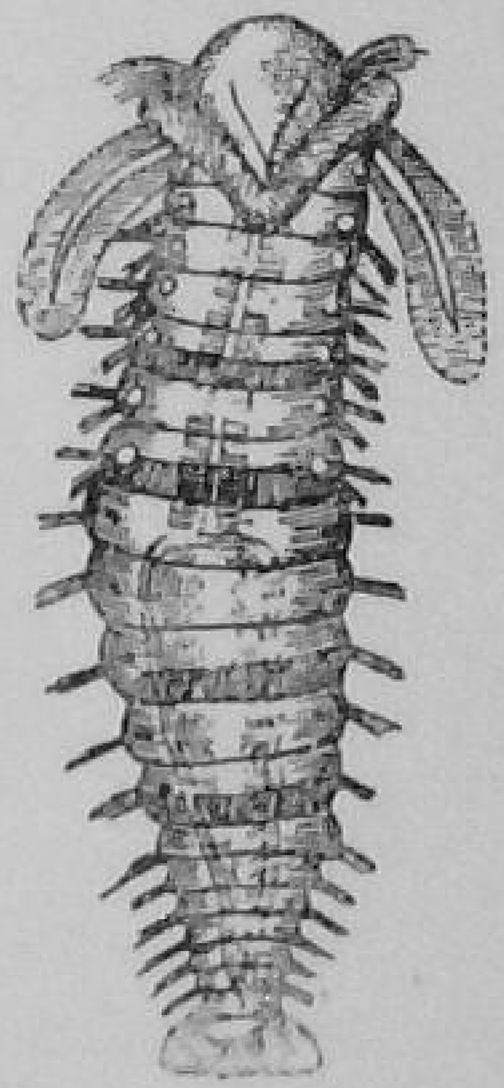

FIG. 2.—Floating larva of an annulate sea-water worm, known as the Sea Mouse, belonging to the genus *Polynoe*. The adult lives on the bottom; its larva, one or two millimetres in length, forms a part of the plankton carried along by the currents.

The vegetables have a less obvious part. They are almost entirely limited to *Protophyta*, which are unicellular plants, elementary in structure and microscopic in size. Their principal groups are those of the Blue-green Seaweeds and Diatoms and the Dinoflagellates The Blue-green Seaweeds, closely related to the Bacteria, are among the tiniest and most elementary of all beings endowed with life. Their substance, devoid of any nucleus, or composed of diffuse and granulated nuclear matter only, is sometimes colourless, sometimes tinted with a greenish-blue pigment, phycocyanine, which permeates it sometimes in association with chlorophyll, the green colouring matter of plants. The Diatoms and Dinoflagellates are beings of a higher order, despite their smallness and rudimentary organisation. They have a complete cellular structure, often containing chlorophyll; their tiny bodies are surrounded by a strong envelope, a thin piece of cell wall often regular and

geometrical in shape, which is composed of proteins combined in the case of the Diatoms with silica, and in the Dinoflagellates with pure cellulose. The latter occupy an ambiguous position among lower creatures, for, while their chlorophyll and cellulose suggest a similarity to plant life, their possession of movable filaments, which they move in the water like whips, suggests a relation to the animal kingdom.

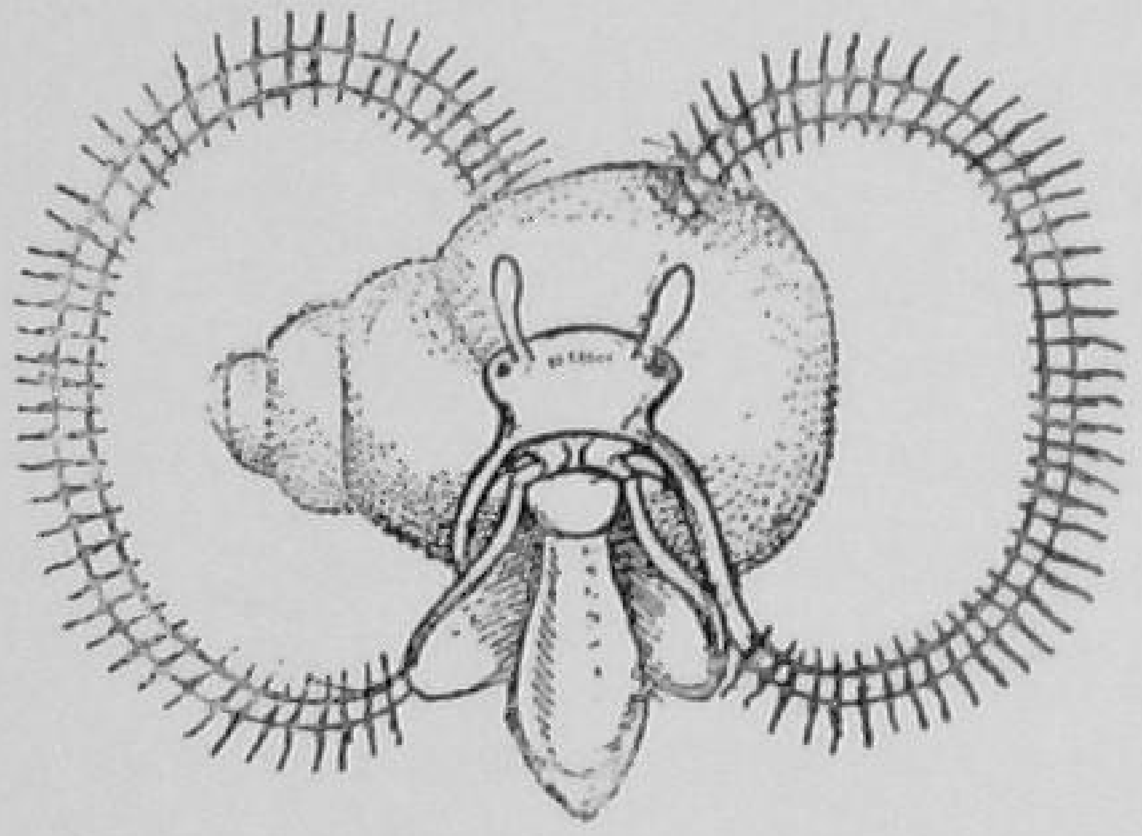

FIG. 3.—Floating larva of a snail-like mollusc of the genus *Rissoa*, with its little spiral shell, from each side of which spread out the two broad filamentous outgrowths which enable it to float in the water and form part of the plankton. Later, its shell grows and becomes heavier, and it sinks to the bottom where it develops into the adult form.

This vegetable plankton, this Phytoplankton, to give it its proper name, because of its uniformly simple structure and minute size, stands in very definite contradistinction to the animal plankton, or Zooplankton, which is much more abundant and more varied. If plants, by their mass, outweigh animals as inhabitants of the land, the animals have the advantage in the world of waters. Not only do the floating creatures include Protozoa, unicellular beings comparable to the Protophytes as regards size and mode of life, but they present us with representatives of many animal groups, even the highest. The huge squids and many fishes, even very large ones, like the sharks, belong to this category, and also the great Cetaceans, whalebone and sperm whales, grampuses and dolphins, for they swim and float from birth to death and are stranded only by accident. These giants of the animal world are as much a part of the plankton as the smaller

creatures, even those which cannot be seen with the naked eye, though these make up for the smallness of their size by an astounding rate of multiplication. Every extreme, both in structure and in dimension, is to be found among these floating, wandering creatures. They cannot be measured by our standards, or judged by norms based upon our common sensations of sight and touch. If we would gain some idea of their reality, we must find new standards by which to form our judgments.

In this animal plankton the most abundant are also the tiniest. They serve as food for creatures larger than themselves and so enable the whole to subsist. Among them, the Protozoa, at the bottom of the scale, and many microscopic species besides, afford examples of more complicated and elaborate organisms, phosphorescent *Noctilucæ*, and Radiolarians with a beautiful siliceous skeleton. Higher up the scale, but still of restricted dimensions, for they are never more than a few millimetres in length, are the Rotifers, the floating larvæ of a great many different animals, the little crustacea of the orders of Phyllopods and Ostracods, often given the nickname "Water-fleas," looking like miniatures of swimming shrimps. These creatures make up for their smallness by their profusion, and play a preponderating part in the general economy of life in the waters.

The jelly-fish, whose bell-shaped bodies are fitted with long, flexible tentacles, may also be considered among the most characteristic examples of floating animals. Their translucent flesh, sometimes faintly tinted and opalescent, sometimes almost completely transparent and nearly as clear as glass, sometimes bordered or otherwise adorned with brilliantly coloured areas which make them the more striking, gives them an appearance of softness and fragility. When stranded on the shore, they rapidly disintegrate and the waves soon dispose of them. Far out at sea they float in the

water and often form extensive shoals covering great distances. Sometimes, ships that happen to come upon such shoals have to steer their course through them for hours on end.

Some of them are phosphorescent. I remember, one night when the weather was bad, sailing across the channel between the island of Aurigny and Cotentin Head. This particular voyage is sometimes especially difficult because of the strength of the tidal currents. On this occasion, my boat passed through a shoal of large jelly-fish. Their luminous splendour was enhanced by the swiftness of the current which carried them along. Piled one above another, they looked like huge glistening spheres rising from the sea like set pieces in a firework display provided by the genii of the waves, an astounding illumination coming from the very depths of the waters.

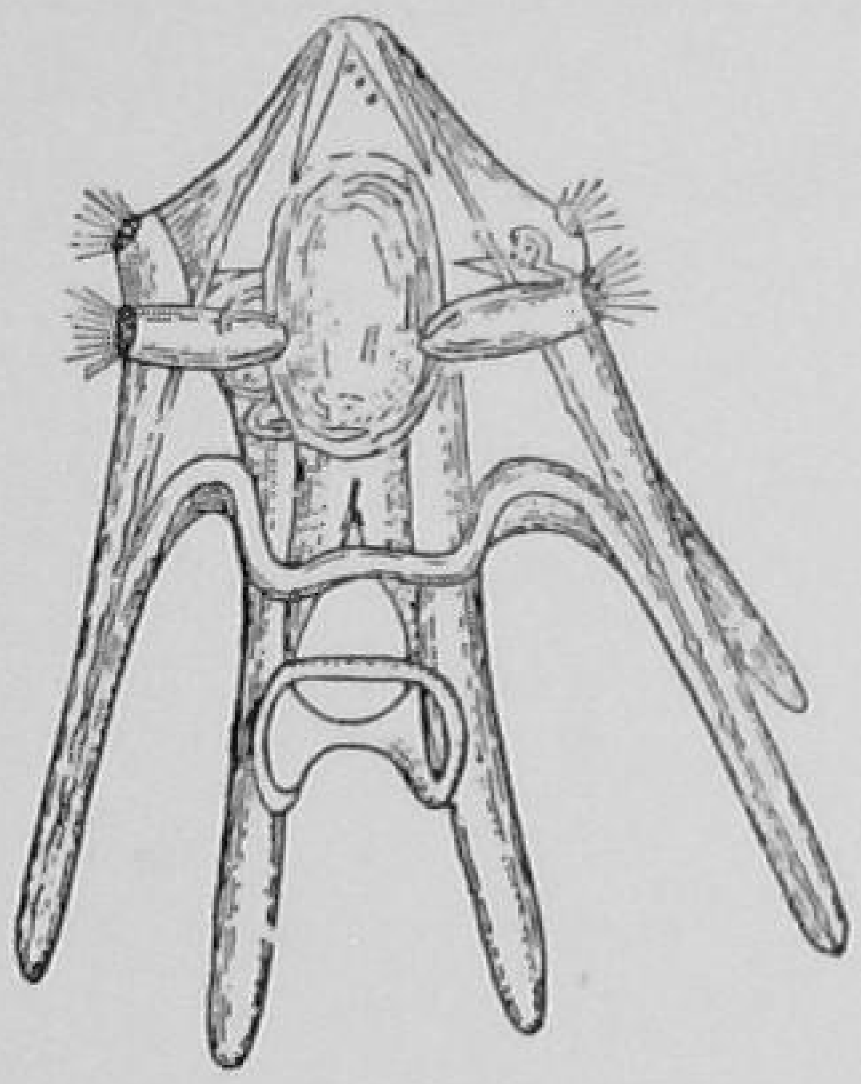

FIG. 4.—Floating larva, called *Pluteus*, of the common edible sea-urchin. The adult, globular and spiny, about 2 inches wide, lives, almost motionless, on the bottom. In the larval state, when it is very small, it forms part of the plankton.

Other floating animals have translucent flesh, the Siphonophores, or composite jelly-fish, the Ctenophores, or comb jelly-fish, with their long tentacles, the phosphorescent sea-squirts or Pyrosomes, like knob-covered little sacs made of a material as clear as crystal but very strong, the barrel-like sea-squirts or Salpas, attached one to another like the links of a chain stretching out into the sea, the wing-footed Molluscs, or Pteropods and Heteropods, several of which are covered by a translucent shell. Big enough to be seen in the water; so numerous, sometimes, as to cover mile after mile; sometimes crowded upon one another, so that they

form great masses; sometimes sparse and scattered, they can be caught from a boat in a landing net, or collected in a glass bowl with a sufficiently broad opening. Professional fishermen, who often come across them, know them well; and though they may have little use for them because they have no market value, they have many stories to tell about them, the origin whereof goes back to the remote past. They point to portions of the clothing of Venus, the daughter of the ocean and goddess of beauty, though, truth to tell, there was not very much of it—a girdle and a pair

FIG. 5.—Floating larvæ of Crustacea. Left, spiny lobster; right, common shore crab. The former is called *Phyllosoma* or the glass-crab, and the latter *Zoea*. As they grow, they become heavier, and end by sinking to the bottom where they become adult.

of slippers. The girdle is to be seen in the broad, flat, translucent body of a Ctenophore, Venus's Girdle, which swims with an undulating movement; the slippers are the transparent shells of floating wing-footed molluscs, Cymbulias, which sometimes disport themselves in shoals on the surface of the water.

These varied, diverse creatures are not the only ones. Beside them, among them, and, like them, always floating about, may be reckoned the different species of fish which hunt them down and pursue them for the sake of their flesh, hunting and pursuing one another for the same purpose at the same time. In good weather, I have seen boats all round me, manned

by regular fishermen, putting out nets to catch these fish by which they make their living. With them and through them, they benefit by this intense life which the sea affords in unsparing profusion.

At different times and in different places I have watched men fishing for sardines, anchovies, herrings and mackerel, all fish which, when very young, live upon tiny crustacea, and other small creatures spread in myriads over the bosom of the waters. In certain

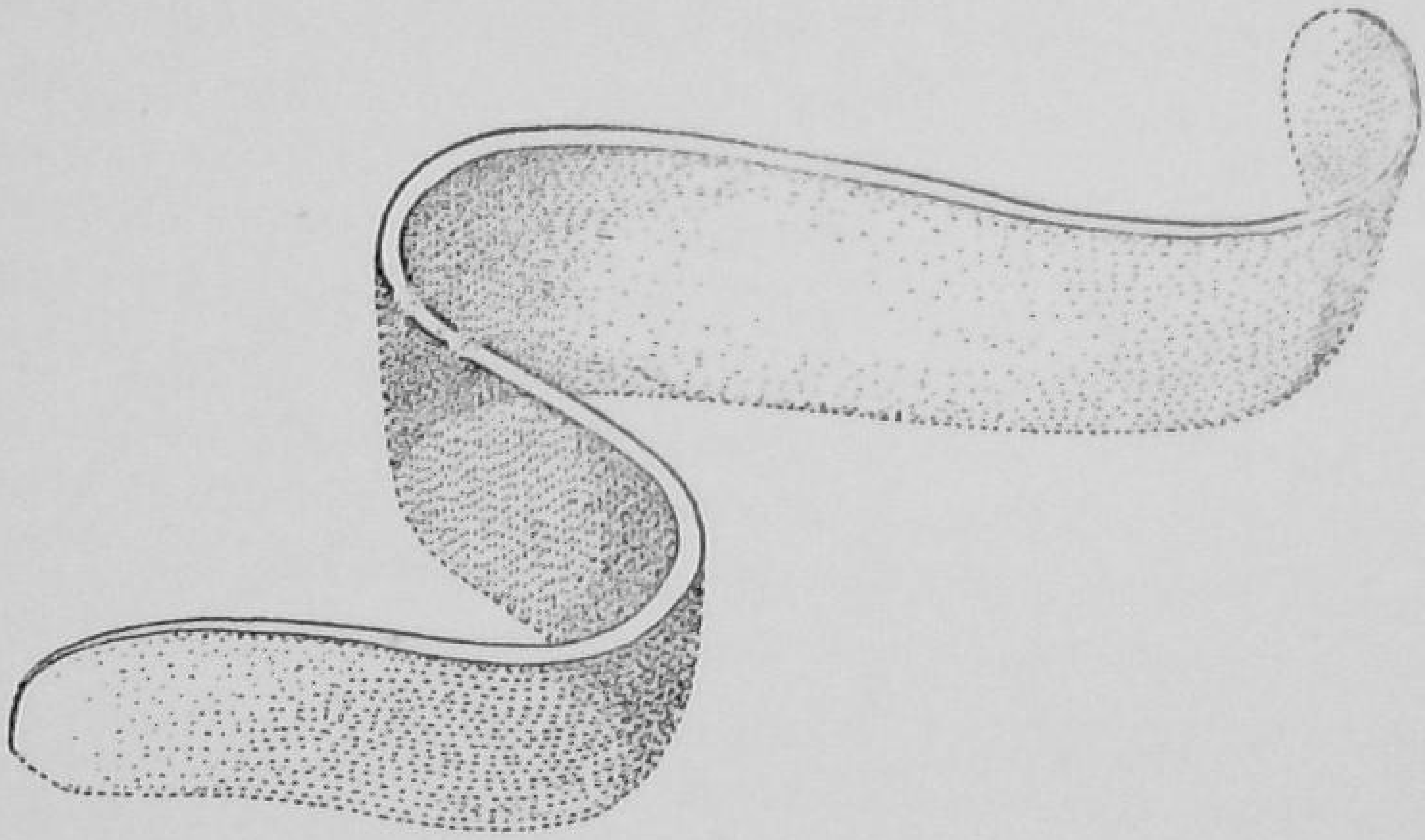

FIG. 6.—A Ctenophore, or comb-jellyfish, Venus's Girdle. The animal is over a yard in length.

carefully chosen places, I have seen great systems of nets, set out not far from the shore, to catch the bigger and stronger fish which hunt down and feed upon the smaller species. Occasionally, I have seen still more powerful creatures, large sharks, porpoises and dolphins, which, in their turn, seek to devour the smaller fish. The sharks pursue the tunnies, the tunnies pursue the sardines, and the sardines eat the little crustacea which feed upon the floating unicellular organisms. Such, in a nutshell, is the picture of this constant chase after food, the larger ever pursuing the smaller, which makes up the lives of this vast host of

creatures differing widely from one another both as regards construction and size. All float in the immensity of the waters. All are suspended in those waters, there remain suspended without remission and without end, peopling the waters from the surface to the very bottom.

This bottom is inhabited. Upon it settle and attach themselves different sorts of animals, from near the shore to the very limit of the depths to which light can descend, the light essential for the function of the chlorophyll, together with a host of seaweeds and other marine plants. Among these animals, some settle only for a while and then begin moving again, going and coming, crawling or swimming. Others, more extraordinary, attach themselves to the bottom and fix themselves there definitely, manifesting their animal nature only by contractions and extensions of their limbs. Such are the corals, certain worms, many molluscs with a double shell, and several others. The rocks, up to the limits reached by the highest tides, sandy beaches, the coast-line generally, the huge muddy bottoms, support in this way a host of settled inhabitants, often so abundant and close together that they cover everything and give the impression of vast profusion. Near the shore we may see rocks covered with a compact carpet of mussels, packed so close that there is not the slightest space between them. At low tide, if we lift the pebbles and delve beneath the rocks, we find masses of other creatures living in groups, forming a heterogeneous, but very much alive, association of species of many different kinds. This abundance is interesting to the naturalist, for in it he finds, as though in a garnered heap, the materials he uses for his studies: it strikes the ordinary casual observer by its contrast with the much more scanty population of the neighbouring land. In its own way it expresses the marvellous number of actualities of life which the world of waters contains.

But this population fixed to the bottom is not really very large; it covers the bottom only in places; it penetrates a little way into the mud or sand, and goes no farther. The population which floats in the water, which allows itself to be carried along by the water or else moves by its own power, is more varied. It occupies the entire mass from the bottom, hundreds and thousands of yards below, to the surface. It

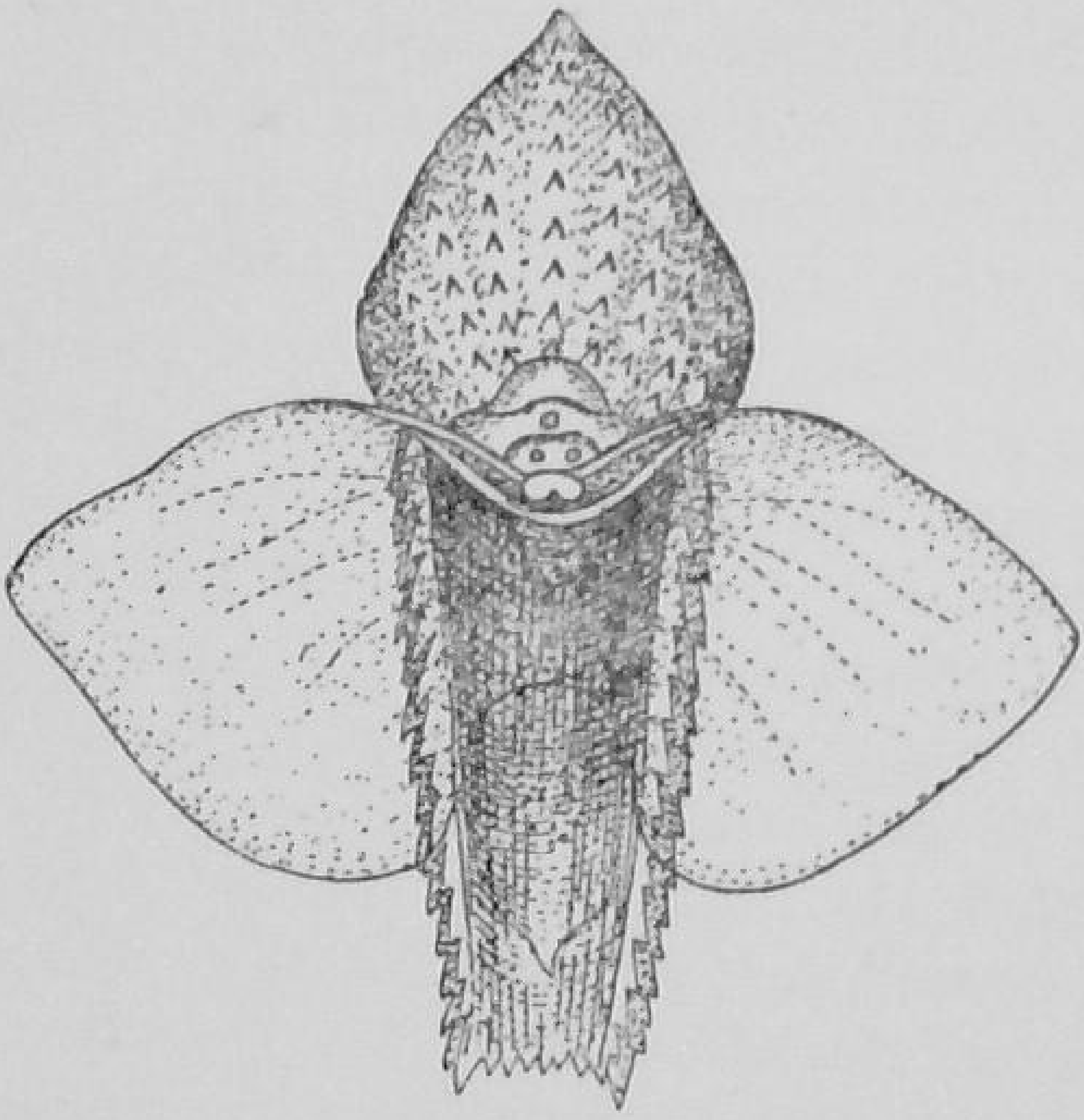

FIG. 7.—One of the Wing-footed Molluscs, Venus's Shoe. The figure shows the transparent shell in the shape of a shoe. The hollow contains the animal, with the two outgrowths which enable it to float. The shell usually measures about two inches in length.

extends in breadth as well as in depth. Sometimes spread out and scattered, almost lost in the vast volume of its environment, elsewhere it is gathered in extensive, closely packed shoals, in which millions of individuals, as closely packed as the mussels on their rocks, fill the waters of the surface for several yards in depth as far as the eye can see.

In certain localities, like Villefranche near Nice, where currents, richly populated by these floating creatures, often approach the shores from the open sea,

strange sights are frequently to be seen. When the current bears along tinted animals, such as little sail-bearing jelly-fish, the Velellas, which are like violet plaques, they surround the boat as it lies at anchor and envelop it with a continually renewed stream. Round us we see these creatures rise as they slowly draw near, borne by the current, pass on either side of the boat, then disappear, unceasingly replaced by others like themselves, which approach and go off again in the same way. For hour after hour this uninterrupted stream of living creatures borne by the sea comes and goes, slowly, softly, silently, with a smooth, continuous movement, like a seemingly endless series of cohorts.

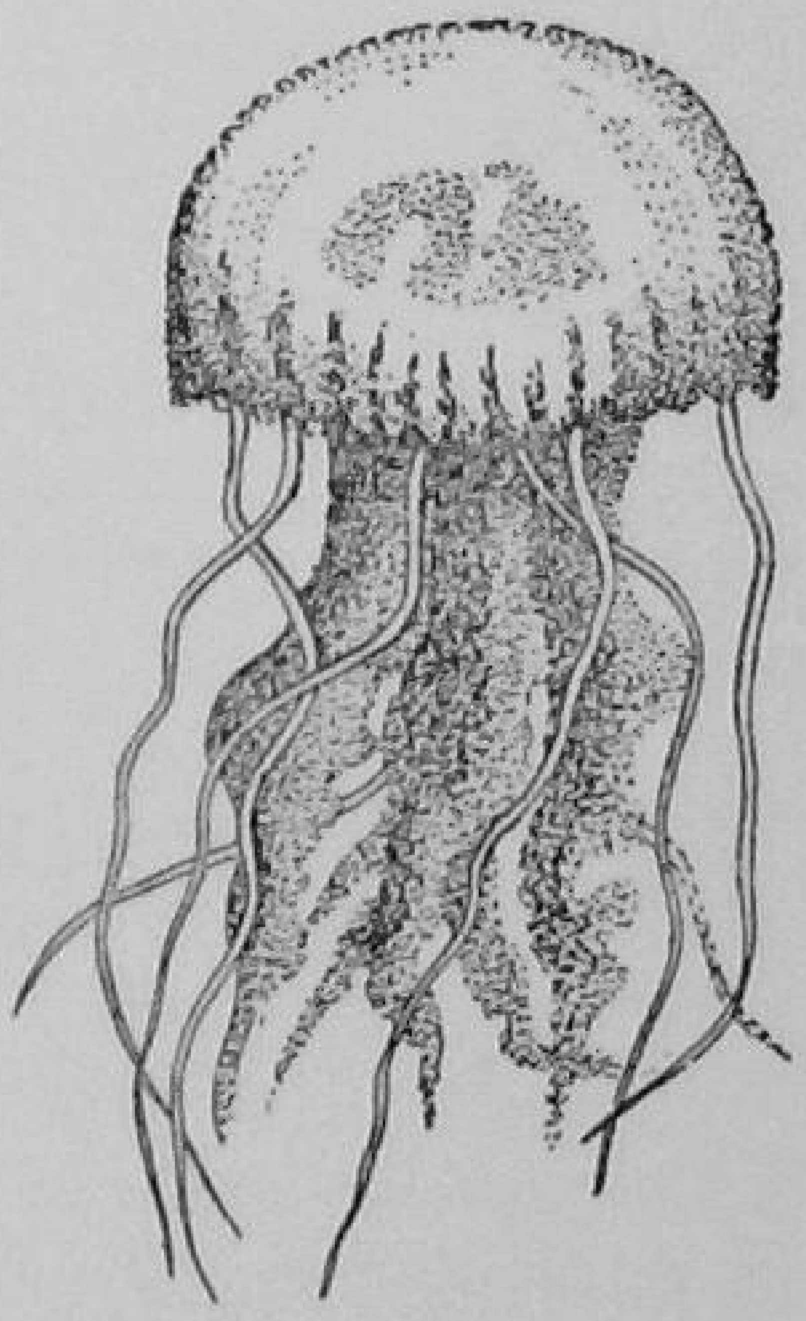

FIG. 8.—Phosphorescent Jelly-fish. The diameter of the dome-shaped umbrella may be four inches or more.

The myths of antiquity, founded upon a keen observation of nature, are to a certain extent based upon fact. When Neptune, before the assembly of the gods, boasted of the extent and wealth of his empire, he only announced a truth which modern science is perfectly ready to admit. His subjects are, indeed, the most numerous and the most varied of all living things. Their guardian Proteus, who acts as their shepherd and has the power to change his form at will, is a symbol of their diversity. When we have looked upon the astounding spectacle of these shoals of floating beings, borne by the currents, stranding, sometimes, upon the shore which they strew with their remains, we see the shining sea, sparkling in the sunlight, with other eyes. We see

it as it really is, a vast, untiring womb from which existences issue unceasingly.

The atmosphere contains beings that are able to live and move in it, varying according to place and time. These beings are forced, constrained by the force of gravity, to rest occasionally before they set off again. Its giants are great birds like the eagle, the condor, the albatross. The dust carried about by the winds is mainly composed of the sterile debris from rocks and stones. How very different is the realm of the waters. Throughout its length and

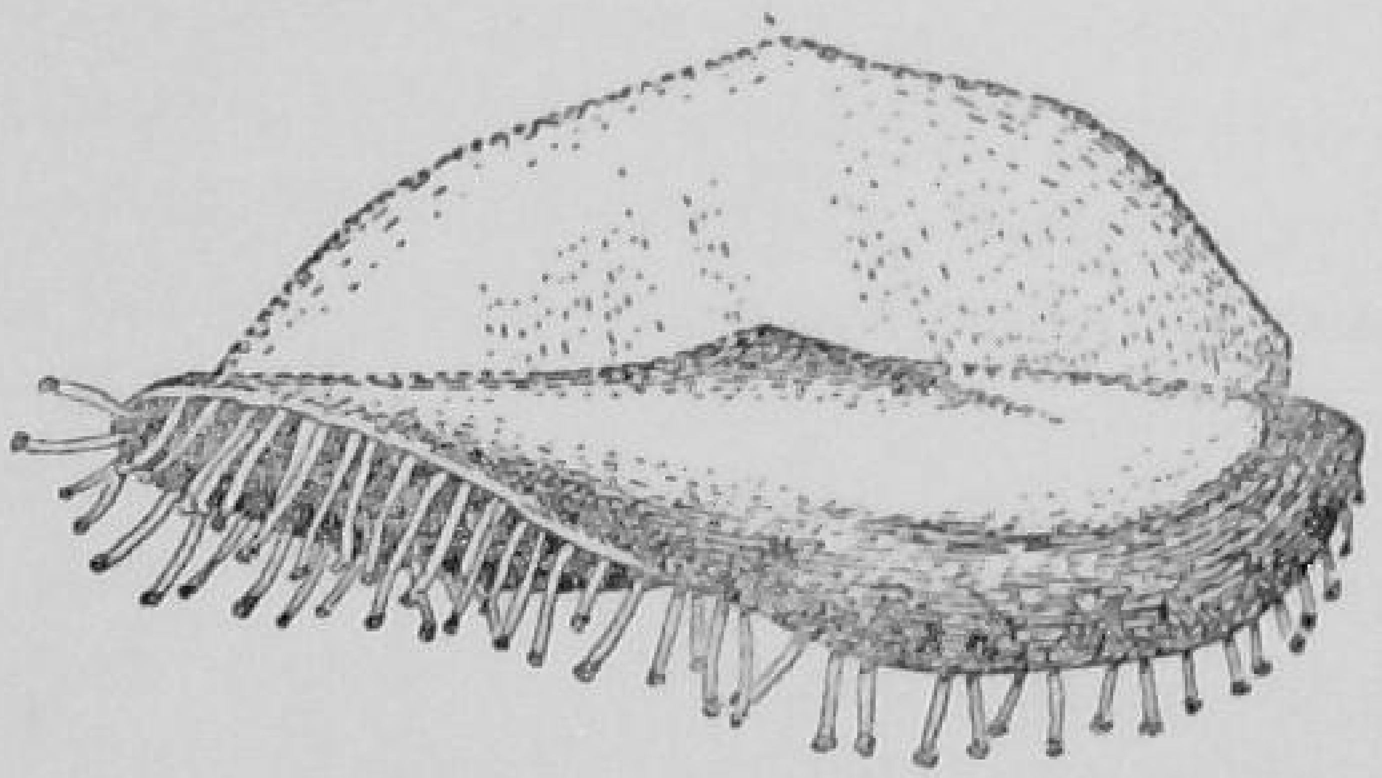

FIG. 9.—Sail-bearing Jelly-fish, showing the keel-shaped float with little cylindrical polyps underneath. Natural size.

breadth it is packed with a host of creatures which dwell in it permanently, float in it continually. Its giants are great monsters: cachalots and other whales, sharks, greater in size than the hugest of land animals. Its dust, the dust borne by the currents, is a dust composed of living beings which reproduce themselves, whose multiple and successive generations take from the surrounding water only the materials of which they are constructed. Its wealth, its might, are in striking contrast to the niggardliness, we might almost say the meanness, of its rival, the atmosphere. Both maintain life, but by means and with results very different.

The animal and floating population of the waters,

thus contrasted, appears imposing beyond all proportion. The space it occupies extends over more than two-thirds, almost three-quarters, of the total surface of the globe. It goes down much lower than the flying population of the air goes up. Regarded as a mass it is infinitely greater than the latter, even if we include the creatures that have settled upon the earth. In it, everything is in contact and in relation, the lowest and least with the immense. The water, fluid, adaptable, but coherent, surrounds it and supports it without ceasing.

Among these creatures we do not find the precise shapes we see around us on land, movements controlled by gravity, flashes of action limited in scope and quickly checked. In them movement is easier, while action is more sustained and kept up for longer periods. Thanks to its density, which is not very different from that of living bodies, the water actually favours the vital processes. Paying no heed to differences in form, structure, size, in other words to disproportion of every sort, it lessens their effects, and produces a certain measure of uniformity. It confers a kind of homogeneity upon everything which its mass contains, thus reconciling what appears to be irreconcilable. Within it the vital actions, of whatever nature, acquire a degree of co-ordination. In it everything is intermingled; strife is everywhere, but so is mutual assistance. There is a universal law to which everything is subject in spite of its extension in space. This world of waters, in the cohesion of its fragments, bears within itself the greatest sum of life upon the globe.

Here again, there is something significant in the fancy of the Ancients. Prometheus, fastened to his rock, is punished because he has stolen fire from heaven and tried to discover the truth of things. Chained, lamenting his melancholy fate, he bewails the fact that he was ever born and is in despair about

his future. Then the Oceanids, daughters of the waves, rise about him, console and encourage him; they bring him aid and help him to bear the evils Fate has laid upon him. The earthly world, in which we are enchained in so far as we are bound to live in accordance with the exigencies of our organisation, is becoming tiny. The progress of science makes existence easier and so increases the human population, but, within the narrow confines of the continents, cannot, at the same time, increase proportionately the resources at the disposal of that population. The earth is small; travellers tell us that they never can say when and where they will come upon someone they know. The seas are ready to provide what is lacking. Their resources are considerable. Far from being barren, they are fertile and produce in plenty. That produce, unlike the produce of woods and fields, has comparatively little of the plant in it; it is made up principally of animals, but is none the less a valuable offering. The gift of the Oceanids is still worth having. Man, the latest arrival upon the globe, becomes the beneficiary of all the resources accumulated by the life that has preceded him.

The necessity of taking from the world of waters and making full use of that vast treasure-house demands our attention and our effort. Human science began by investigating the earth and its produce; it is continued by the exploration of the seas. It set out with geographical expeditions; now, except in a few remote places, it has found out what it wished to know and accumulated a store of knowledge. At the present day, by means of oceanographical cruises, it is continuing to learn all that is to be learned about its new domain. Along the coast, in nearly every sea, laboratories are being built, so that the produce of those seas may be studied and we may learn how to make use of it. Such an attitude, such enterprises, are characteristic of the time in which we live

and show the direction in which we shall have to progress.

In very truth a part of our future rests in the waters. We have only to go and find what there is in those waters and make use of it. Man began with the conquest of the earth: henceforth he must concern himself with the conquest of the waters.

CHAPTER II

TUNNIES AND THEIR RELATIONS

We often say of a good swimmer that "he swims like a fish". And this remark very well expresses what we feel, for the capacity to swim is the quality we notice first about fishes. We have every excuse, therefore, for comparing a good swimmer to a fish.

The comparison, however, is not so apt as it might seem. The fish, which is made to live in water, moves easily in that element, but the same can hardly be said of ourselves. Our lungs will not allow us to stay long under the water. Our broad chests hinder us from cleaving our way easily through it. Swimming for us is by no means child's play. Many people practise it, but few really become masters of the art. It takes a strong constitution, hard and vigorous training, to become one of those experts who, apparently with little effort, dive, come up again, then dive once more, moving as comfortably at the bottom of the water as on the surface, and, by their agility, reminding us of fishes.

The motions of swimming, so far as we are concerned, are unnatural. The quadrupeds, better off than we are, only beat the water with their feet as if they were walking or running, and so can support themselves in the water, and even make progress. Not so in our case. We are taught to stretch ourselves out, lie down, and move our limbs in an almost horizontal plane, and this position only allows us to get the advantage of a limited part of the muscular effort we have to make. Consequently, the progress made even by a very rapid swimmer is not so great

as that which he could make on land, even if he did not go very fast.

But the adoption of this position has its advantages. We can modify the movements of our limbs and co-ordinate them in such a way as to select the most useful and make the best of them. There are many methods of swimming, and we can take our pick of them according to our strength and physique. Here, as elsewhere, personal qualities come into play. This we can observe at any swimming competition attended by the best swimmers, and there are many of these in our northern lands. I have seen swimming races in which many of the competitors showed great prowess; they all used the same methods, but they all differed both in manner and in results. If we except fencing, there is no other form of exercise so diverse or so well adapted to individual idiosyncrasies.

There are many ways of swimming. In the breast-stroke, both pairs of limbs act as propellers simultaneously; the body moves forward with a certain amount of difficulty, since the solid mass of chest and shoulders must overcome the resistance of the water, and this to some extent holds up progress. In the trudgeon stroke, on the other hand, the swimmer tries to drive himself along by reducing the resistance his body offers to the water. He lies slightly on one side so as to present only one shoulder to the water, thus avoiding the flat position; the two arms reach rhythmically beyond the head, either together or one after the other; they cut the water and so facilitate progress. The legs, as in the breast-stroke, are the main propellers; the swimmer pulls them in, then thrusts them out vigorously to their full extent, completing the stroke by drawing the feet together. In this way, pushing his body forward from behind, he presents only lines of least resistance, and so gains the highest degree of advantage from the effort he makes.

This method, swifter than the other, only reproduces

as far as we are able the method which nature employs in the best of all swimmers. In their case, as in ours, the essential motor is behind, and the body is constructed in such a way as to offer a series of slippery planes which the water strikes against but does not cling to.

The animals which swim best, most quickly, and for the longest space of time, are the Cetaceans of medium size. They are the dolphins and porpoises, sometimes called sea-pigs,[1] whose length, less than that of gigantic whales like the cachalots, is seldom more than six or eight feet. Travellers by sea often have an opportunity to see them. By racing alongside and often travelling faster than the ship, they provide a diversion for the passengers on a long and tedious voyage. Sometimes they are seen in couples, male and female, sometimes singly, more often in companies or "schools". As soon as one arrives, the others come too. We see them a little way off, showing not the slightest sign of fear, exposing, at regular intervals, their curved, shining backs, diving, coming up, diving again and reappearing in a continual repetition of the same undulating movements. They keep alongside the ship, never allowing themselves to be outdistanced. They swim in a series of bounds, and their course, if followed by a pencil on paper, would appear a series of waves. Sometimes these occasional companions follow the ship hour after hour, now drawing nearer, now going farther away, or hastening from one side of the ship to the other. Sometimes they fall back for a time, or disappear, only to return in a little while, but not leaving the neighbourhood of the ship. Whatever the speed of the ship, they accommodate their own speed to it, never giving way.

Several years ago, the sardine fishermen in a little Mediterranean port found almost every day that their

[1] The French word *marsouin* is an adaptation of the German *Meerschwein*.

nets had been torn by a school of porpoises which came to seize and feed upon the netted fish. Their sharp teeth cut through the meshes. The fishermen complained to the appropriate government department, which sent them a torpedo boat armed with a small gun to fire at these unpleasant visitors and frighten them off. I knew the commander of this vessel and persuaded him to allow me to go with him the first time the ship put out. We went straight out to sea, to the place where the porpoises usually appeared. Soon we saw them. As usual, they approached us on both sides, and began to convoy us. At that moment, the torpedo boat was going at full speed and making about thirty knots an hour. But. despite this great speed, the porpoises outdistanced us easily. They turned under the bows and played all sorts of tricks about the ship without seeming in the least perturbed. We watched them for half an hour and then decided to try and shoot one. We missed. The porpoises dived, vanished, and did not appear again before evening. But the following night they came back to the fishermen's nets and continued their depredations by ripping them open again. As soon, however, as they saw the torpedo boat coming out, they recognised it and took to flight, only to come back again when it had disappeared.

These porpoises, or perhaps dolphins, clever and tricky as foxes or wolves, are not fish. They are mammals, and represent that class in the marine world, together with the cachalots and other whales, with which they form the order of Cetacea. The females produce their offspring alive and feed them on milk. They breathe through lungs and are compelled to come to the surface at regular intervals to get the air they need. Their fore-limbs do not look like legs with paws, but like paddles or fins made all of one piece and flat. Their body ends in a broad, thick crescent, spread out like a fin; but this is

horizontal, whereas that of fishes is vertical. The hind limbs are atrophied, and the bulky masses of muscle, the true tail, at the end of the trunk actuate this tail-fin and supply a propelling power seldom possessed by the terminal appendages of other animals.

When we examine one of these creatures out of the water we are surprised at its shape. It looks like a fish; its body is spindle-shaped with tapering surfaces, but it is thickly built, broad, and provided with a thick cushion of fat under the skin. We hardly expect to find a creature like this, built almost clumsily, instead of the slender, swift-looking creature which its great speed gave us every reason to look for. It is very like the greater cetaceans, the whales. But when we examine its construction more carefully we cease to be astonished. The plump body, buoyed up by its fat, has the rounded contours which let the water slip past; and the two paddles in front serve to maintain the balance. The chief propeller, the broad, powerful tail with its fin, beats the water with an up and down movement, and thrusts the animal forward. Each beat forces the body upwards and forwards in such a way as to produce a series of successive bounds, sometimes very close together, sometimes at a greater distance.

Most fishes cannot swim so swiftly. They have a caudal fin, often, in comparison with their size, as large as that of the Cetacea, but it does not often have so much muscular power in front of it. Moreover, the blood, which conveys to the muscles the oxygen they need to produce their energy, is not so rich. The fishes belong to that category of animals called 'cold-blooded', or of variable temperature, in which the respiratory oxidations which stimulate vital activity remain on a lower level. The tail with its caudal fin, set vertically, is able to effect a rapid burst of speed which allows the fish to make a dash after its prey, but it cannot keep up this speed for long.

At the rear it acts as a scull, beating the water first to right and then to left, and so pushing the body forward. Only some sharks and the large mackerel or scombers are capable of using this tool with an effect comparable to that attained by the cetaceans.

In the first rank among these mackerel are the fish commonly known as Tunny. They are very plentiful and they have considerable points of difference. They belong to several species grouped in a few genera, which, in their turn, are included with the mackerels in the family Scombridæ. They live in the warm and temperate seas of the world, and are to be found in considerable shoals. As voracious as wolves, always hunting down fish smaller than themselves, their numbers and size enable them to play a preponderating part in the natural disposition and the balance of food in the marine world. European waters contain several of them. In the first place comes the great tunny, the giant of the group, which may be as much as three yards long and weigh up to eight hundred or a thousand pounds, as much as a horse or an ox. Not so large is the albacore, distinguished by the excessive length of its two pectoral fins. Further down the scale, a sort of miniature, come the four-spotted little tunny, and various species of bonito, whose length may be as much as three feet, but is seldom more.

Whatever their species, all these mackerel live exactly the same sort of life. They exploit the seas just as flesh-eating mammals on land exploit the plains and forests. Their size and speed give them a position of dominance which they use and abuse to the full. Not only does their rapid speed enable them to overpower many kinds of prey to an extent only limited by their gluttony, but they are able, further, to keep up this rate of speed over long distances, which other fish are usually not able to do. Though they are not so speedy as the dolphins, their enemies, which hunt

them down in turn, they are often to be seen from the deck of a ship going twelve or fifteen knots an hour and travelling as fast as the vessel when they are hunting on the surface of the water.

The four-spotted little tunny stands out among them. Its relatively small size, its grace, the originality of its colouring, quickly attract attention. It lives in most warm seas, and is caught by fishermen in fine weather in the southern waters of the Mediterranean. In Tunisia, Tripoli and Egypt it is often seen in baskets at the fish-markets, and can be recognised by its pearly, shiny belly, its hardly darker sides, and bluish-grey back, marked with black stripes, some wavy and interlaced, others straight, the smallest short and spot-like. These lines, all mixed up together, look like a mysterious system of writing, consisting, so the story goes, of sentences written in an unknown tongue which, according to the Moslem fishermen, is that of Allah. Its meaning is hidden from ordinary men and understood only by the greatest saints.

These fish, when captured and examined closely upon the boat's deck, or later, on the stalls in the market, are as surprising as the porpoises and dolphins. Judging by their speed, we should expect to find them finely shaped. Instead, they are fat, large-bellied, very different indeed from our anticipations. We cannot understand it. We look still more closely to try and find out the reason for such a contrast between expectation and reality. A detailed study, however, soon makes clear the actual facts of the case, and we cease to be astonished.

The bodies of the four-spotted little tunny and of the larger species of tunny which are even thicker and fatter, are clearly designed for rapid progress through the water. Their spindle-shaped form is constructed along lines best calculated to offer the least resistance. The skin, covered with tiny scales, presents surfaces which are curved and smooth; friction

is thus reduced to a minimum. The conical, pointed head is shaped like a fuse cap. The paired, or pectoral and pelvic fins, which might be an obstacle, are situated close to hollows in which they lie without projecting beyond the surface of the trunk, when the fish is swimming at full speed. When so swimming the tunny is like a spindle of polished steel, made in such a way that it does not present the slightest roughness of surface. Only the median fins project, the caudal fin behind aiding the forward movement, while the dorsal fins above and the anal fin below help to preserve the equilibrium by preventing the body rolling sideways in the water.

The main propeller is at the rear like the screw of a ship; it is not lateral. The pectoral fins, though they appear to do so, play no part when the fish is swimming rapidly; they lie out of the way in their hollow when the body is moving at full speed. In the earliest days of steam navigation paddle steamers had wheels at the side. To-day they are only used in special cases to facilitate handling and landing when there is little depth of water. The paddle-wheels have been replaced by screws submerged at the stern of the ship, and these propellers are less cumbersome, possessed of greater force and greater efficiency. Nature acts in an exactly similar manner. Fishes have their propeller behind them, namely the tail with its caudal fin which acts as a scull to strike the water.

The tail-fin of the tunnies takes the form of an upright blade which is full and sharp, curved in the form of a crescent, almost as high as, or even higher than, the body is thick. Made of two equal halves, one above the other, both are firmly attached at the hinder end of the body to the deep compressed caudal portion which terminates the trunk; and their rays, rigid and strong, have the firmness and solidity which their use demands. When we look at and

handle this terminal fin, we understand the greatness of the effort it is capable of making.

Everything in these animals seems to have been designed systematically for its one purpose. The caudal fin, a perfected scull, is supplemented by a system of balancing fins set in front of it along the medial line of the back and of the belly. The first dorsal is rigid; the second, more supple, is succeeded by a series of miniature fins called finlets. The anal is stiff like the first dorsal, and is also succeeded by ventral pinnules like those of the back. Altogether we have a system of stabilising keels, made up of several parts, some on the top running along the trunk, the others below, all regulating and maintaining the attitude during swimming.

When we look at this caudal fin we still ask ourselves how, despite its size and solidity, it is able to propel a body of such thickness at such a speed. Where is its motor, powerful enough to produce such a result? Again the comparison with a ship forces itself upon us. In a ship the screw is small in relation to the hull, more so even than the tunny's screw in relation to its body; yet despite its minute dimensions, it is able to move the ship by the turning of its blades in the water. The essential factor is the power behind this action, that is, the efficiency of the engine which produces it. We find that the engine takes up a great deal of room in the ship, and that its elaborate machinery of polished metal occupies a considerable space in the ship's body. The enormous power which it develops is communicated to a horizontal shaft, makes this revolve at a great speed; and this shaft, connected in its turn to the screw whose shaft it is, makes it turn also at an equal rate of speed. The little screw gathers up in itself all the power of the enormous machine which acts as a motor, and so pushes the ship along.

It is the same with the tunnies. Their propeller

is a beating scull and not a turning screw, but this caudal scull is nevertheless attached to an internal shaft set in motion by the considerable mass of muscle which composes the greater part of the bulky trunk. If, like the propeller of a steamship, it seems small in comparison with the body, on the other hand the muscular mass which is designed to impel it takes up a space whose great size is an indication of its capacity.

Nature has even improved upon the science of the shipbuilder. In the construction of the various parts of this mechanism it has introduced an arrangement by sections or compartments which ensures a degree of suppleness while it secures rigidity. The shaft which works the caudal fin is none other than the spinal column, constructed of bony vertebræ which are solid, succeeding one another, connected by intervertebral ligaments which form little cushions. In the medial and anterior regions of the trunk, the vertebræ, thicker there than in other parts, ensure to the shaft they form a firmness like that of the ridge-pole of a roof, but in the posterior, caudal zone, where they are not so thick, the shaft is flexible, elastic, able to bend to right and left, and so to give the appropriate movement to the scull.

Even this arrangement, remarkable though it is, is surpassed in perfection by that of the musculature. The latter, designed after the same manner as the spinal column, is divided into a series of segments on either side of it. These segments are in pairs and are like disks placed one on top of the other from the front of the body to the back. They are attached to one another by transverse membranes which form a sort of joining wall. Each of these is attached to the centre of a vertebra so that the osseous system and the muscular system, arranged in corresponding segments, work together perfectly. Now we are in a position to understand how this living machine works.

When these discoidal muscles contract, they pull upon the joining membranes and these, in turn, pull upon the vertebræ. They act directly upon the spinal column or, in other words, upon the shaft which is terminated by the propeller. If the fore part of this shaft, the coherent part, does not move but simply acts as a support, the part behind, on the other hand, bends alternately to right and left according to the muscular contractions of both sides. In this way it conveys to the caudal fin its power of beating the water and so sending the fish forward, and furnishes it with an intense power which it employs in accordance with this constitution.

Several details in the internal arrangement of this organisation add to its functional capacity. The tunnies, which are large or comparatively large animals, are chopped up into slices in the fish markets and so sold. We see that each of these slices is made up of concentric rings, most of which make four groups, two on the right and two on the left, flanking the spinal column in the middle. These four groups give us cross sections of the discs, one above and one below on each side, and these represent the muscular segments. Their appearance is due to the fact that these segments, instead of extending vertically from above downwards, fit into one another and form folds as a number of wafer cornets, placed one on top of the other, would do. When the fishmonger's knife cuts across the fish, it meets quite a number of them, and they appear in the slice like rings fitting into one another.

There is a definite purpose in this construction. It increases the power of action. This fitting in of the segments brings together the separate efforts of each and makes them all work together to the same end, assembling them in such a way as to be able to apply them all at once to the hinder part of the trunk, the true tail with its caudal fin. Like the screw in relation

to the ship's engines, the propeller of the fish benefits by the accumulated force of all the muscles which make up the flesh of the trunk. Now we understand the reasons for the swiftness of the tunny, a swiftness greater than that of most other fishes. Its body seems

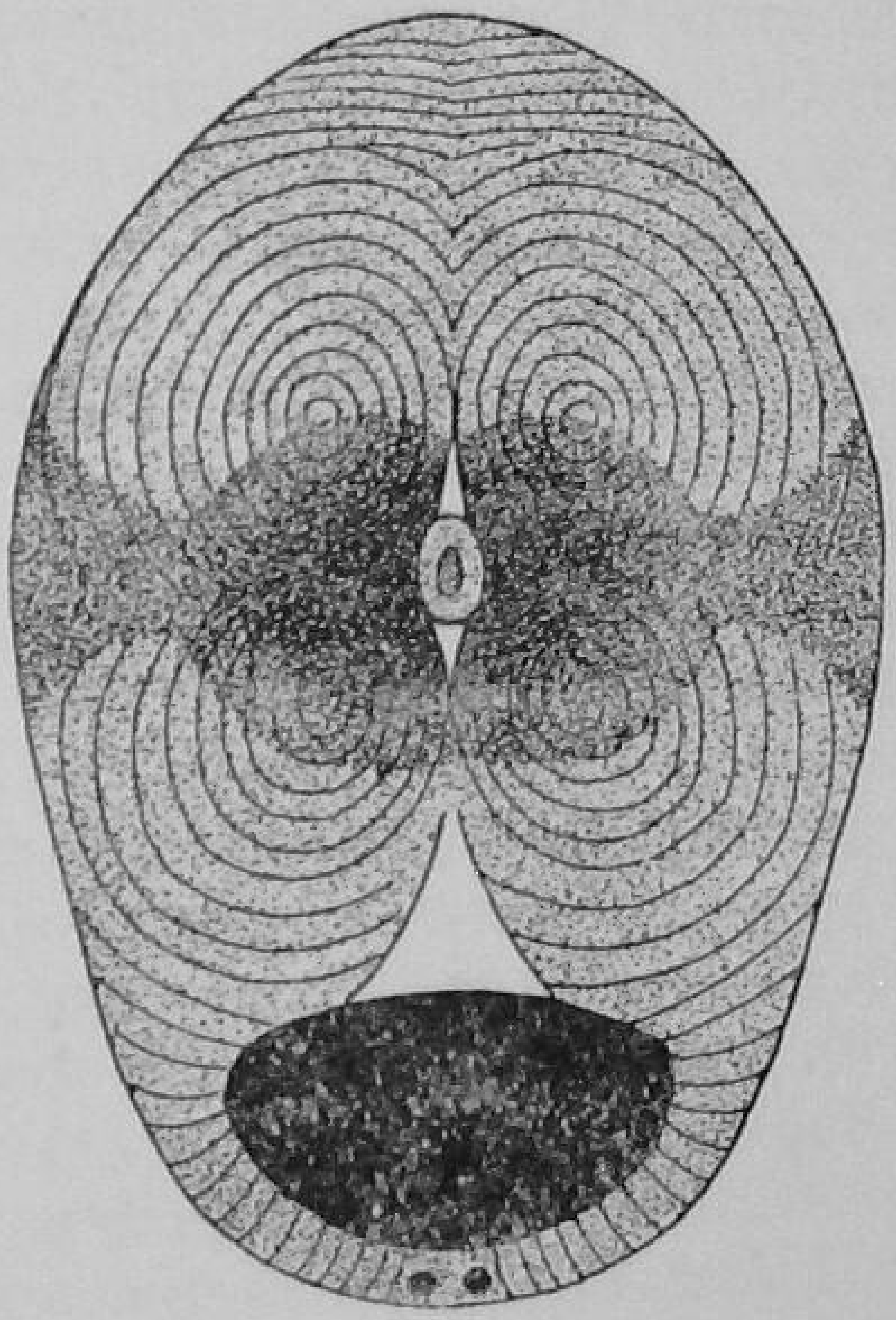

FIG. 10.—Transverse section of a Tunny's trunk, showing the muscular segments like fitted discs which form the flesh. In the centre is the vertebra (in white), and, below, the abdominal cavity (in black). The shaded zones are those which, since they have a considerable wealth of blood-vessels, are distinguishable from the rest by their dark red, almost black colour.

corpulent, but this is due to the greater size of the muscles which produce the motive power; the calibre of these muscles being greater, the power they develop is greater also. In the tunny we may see more clearly than in any other fish the action of this tail-swimming, which begins with a tremendous muscular effort and ends in the oscillation of a propelling scull as stiff as a flail. Certain complementary features in these fishes

make this even clearer. The circulation of the blood, a very necessary factor in the case of such active muscles, is extremely rich; the flesh is deep scarlet in colour in consequence of the abundant blood it contains; the muscular zones most closely in contact with the vertebræ are a mass of closely packed tiny blood-vessels and they have a still darker, almost black, colour. The energy put forth during swimming is indicated by an appreciable rise in temperature, particularly in the dorsal muscles, which are most constantly employed. The whole construction of these large scombers is designed to make of them, like fast ships, the greyhounds of the sea.

Many other fishes have a similar conformation, and use their caudal fins as sculls. But, in most of them, the action is weaker and the power developed less. The fin itself is often, proportionately, larger than that of the mackerel and the tunnies, but it is not so rigid or so strong. It bends and waves in the water, and the zone in which it is actively effective is not so great. The trunk muscles have their four groups of motors with segments and rings; but they are not so thick; the blood does not circulate so thoroughly through them and feed them; the work they do produces inferior results. The body may be more slender; it may appear better adapted for rapid swimming, but actually it is slower, for lack of power in the motor and because of the limited capacity of the propeller.

Usually, these fishes use their propelling scull only when they have to make a hasty burst of speed. They generally prefer to use their two pectoral fins, which they employ as oars with great rapidity. The tail becomes a sort of rudder though, when necessary to give a greater speed, it is capable of affording the required impulse. Normally, however, it remains at rest. Such is not the case with the stronger and swifter species which are built to swim at a great

pace, and without resting. Their main propeller is single, median, terminal, and the whole construction is arranged in such a way as to ensure the utmost output of power for considerable stretches of time.

Swimming is often compared to flying, and resemblances between the two activities are pointed out. The rapid flight of a large bird through the air has much, apparently, in common with that of a fish in the water. Both agree, certainly, in that they move about in an environment which contains and envelops them completely; they both differ from progress on the land when the earth always provides the starting-point. But, except for this likeness, they differ in every possible way. The motors and propellers are different both as regards construction and situation. The preliminary action of the motors may be identical, since it is furnished by muscular energy, but its application is carried out in an entirely different manner.

In flying, the density of the individual is greater than that of the air and, since the force of gravity is considerable, the principal effort consists in supporting the body and preventing it from falling. The wings beat in order to support the animal as well as to propel it, for, by reason of its inconsiderable density, air opposes to progress only the slightest resistance. The propellers, the wings, are therefore placed close to the body's centre of gravity, and balance one another while still acting as supports.

Nothing of this sort is true of swimming, especially when the rate of swimming is rapid, as in the case of the tunnies. The main effort is no longer devoted to supporting the body, for the density of the individual and that of the surrounding water are very similar, and the creature has little difficulty in keeping itself up. What is an absolute necessity for the bird here no longer exists or, at least, only in a very slight

degree. Progress, on the other hand, is more difficult. The dense water offers considerable resistance, and the fish must overcome this resistance before it can go forward. It has a motor composed of muscles designed on a model peculiar to itself. When it swims, it uses this motor in the most effective manner possible.

CHAPTER III

THE DIFFERENT WAYS OF SWIMMING

DIFFERENT indeed; more different than one would expect. Beside the first-class swimmers, driving swiftly through the water, the tunnies or thonines with their high-powered propeller at the stern, we find other creatures less favoured than they are, obliged to employ other and less efficient methods. Such diversity of action, when we consider it in contradistinction to the uniformity of the original motive power, for the motor is invariably the muscle with its energy, and to that of the result, which is always progress through the water, gives to life in the waters one of its most characteristic and striking attributes. The body turns everything into a fin, so as to enable the animal to swim.

On a recent expedition I visited the far south of Tunisia, on the borders of Tripoli. At the end of the Gulf of Gabes, dreaded by ancient navigators because of its sudden violent storms, there is a large salt lake, called by the Arabs "Bahiret-el-Bibane", which means "Little sea opened by gates". This is a great broad bay, almost closed at the entrance and so converted into a lake measuring perhaps nineteen miles by eight. In shape it looks rather like a bulging flask, the narrow neck of which is only partially filled by a cork, leaving a space on either side. This cork is actually a little island, with passages or gates on either side allowing communication between the sea and this gulf, which is otherwise completely enclosed. It is not very deep, only a few yards in fact, sometimes hardly more than three or four feet. Its water is pure

and untroubled. The bottom is covered by a luxuriant submarine vegetation, a thick carpet of algæ and grass-wrack, in which all sorts of fishes and other animals swarm, for there, in absolute security, they find an easy prey in great quantity. These fish do not differ in any way from those of the neighbouring sea; they belong to the same species, but they are more numerous and better nourished.

Only a few years ago it was a considerable undertaking to visit this lake. Camels, mules, horses and even an escort were essential. To-day no journey could be easier. An excellent road and a daily service of motor-cars take one there without the least discomfort. A trip that used to take several days can now be made in a few hours. Comfortably seated on soft cushions, instead of in the saddle or perched up on the oscillating hump of a camel, one sweeps through places where formerly one had to halt and camp. In a few hours after leaving Gabes and its splendid oasis, with gardens hidden beneath spreading palm trees, the goal is reached, about ninety miles separating the bay from the town of Gabes.

Though the journey may not take much time, it is exciting. We go through new regions which have very little in common with the more populated places, more policed and less arid, of Northern Tunisia. We meet horsemen wrapped in their burnous, their carbines over their shoulders, their heads covered, over the turban, by a large straw hat with broad brim bordered with coloured balls. We meet caravans of nomads, escorting flocks of sheep and goats, carrying their folded tents and provisions on camel back. We go through a strange country, sometimes undulating, sometimes flat, and often not a living soul is to be seen. The desert is not far away, and we realise its presence.

At the beginning of the journey we leave to the south the bluish mountains where the Matmata live, a

people inhabiting dwellings hollowed out of the rock, set one upon the other, like those to be seen in certain parts of Touraine and Anjou. On our way we come to Medenine, a strange old Berber city, the houses of which look as though they were made of huts piled one on top of the other in a mass, as though to recall the storied grottoes of the mountainous area. We pass close by the ruins of an ancient Roman town, Gighti, whose extent and importance indicate that this country, now denuded, was once rich and well populated. When we tread the flags of the deserted streets we feel the same sort of desolation which we experienced the previous evening when, before reaching Sfax and Gabes, we looked upon the huge circus of El-Djem, almost as large as the Coliseum at Rome, now all alone in gloomy surroundings with nothing but a sparsely inhabited country about it. In the second and third centuries of our era there was a populous agricultural and commercial city here, Thysdrus, richly planted with olive trees and cereals. Gordian, in A.D. 238, took possession of the empire there. Not a trace of it remains to-day. The memories are gone; there is no sign of the plantations, and, as the poet says, the ruins themselves have perished.

The desert invades and extends continually, and when the vegetation can survive no longer, all life disappears with it. The task of civilization consists in stopping the advance of the desert, even making it withdraw, by cultivation and irrigation, as the Romans did in days gone by. Occasionally, after leaving Medenine, we come upon it. The road passes over broad stretches of sand, flat as the sea, with the horizon all around like the circle one sees at sea with oneself at the centre. The smallest object seems enormous; a dog, a sheep, a camel stand out like giants a long way off. The sand which covers the soil has no growth but stumpy bushes upon it. The lightest breeze raises its tiny grains into dust, carries

them along easily, and sets them down on everything. On the road before the car a gust of wind brings the sand, spreads it out like flowing water, then chases it away as quickly as it brought it. Here is dry, shifting land, where life is sparse, where creatures find little upon which to subsist. It is a space boundless and without apparent limit, rendered vaster by the silence, and over the flat earth there is only the sky. Both earth and sky are empty.

These poverty-stricken places are, nevertheless, the domain of bright, abundant light. The rays of the sun come down upon them without let or hindrance, losing none of their intensity, and the traveller must be warned and act accordingly. This is not the scintillating splendour of the sea, in which the water reflects in its little waves the rays of light which fall upon it. There are no flashings of light upon this luminous soil. The light touches it directly and completely, bathing and surrounding all things; even the shadows, fine, light and violet, have a brightness. The eye can see the dancing tremor of heated layers of air in contact with the soil, where the rays of light diverge, producing a mirage, and, from moment to moment, alter the perspectives of everything within sight. When the wind does not blow, nothing moves except this mobile air. There is nothing to see. Now and again, perhaps, one does catch a glimpse of a human being, seeming strangely out of place, an occasional domesticated animal, but very rarely a wild one. This empire of sovereign light is a realm of barrenness, of desolation, of perpetual repose.

The salt lake which it borders is in striking contrast. Its animation, its continual change, are directly opposed to the dryness and immobility of its surroundings. The light of day penetrating the shallow water fosters the growth of a host of green, bushy plants. The heat enables all this vegetation to grow in profusion. In their turn the animals benefit from these favourable

conditions; they multiply, cover the bottom, pervade the submerged foliage. There, more easily than in the sea near by, they find conditions suited to their development; they grow more rapidly, multiply more profusely. This lake is not only a place of refuge, a shelter, broad and undisturbed; it is essentially fertile, made so by the water which fills it, and endowed with an extreme capacity for the production of life, and the fishing industry is not slow to take full advantage of the fact.

The Gulf of Gabes, an exception to the general rule in the Mediterranean, has a perceptible tide. Twice every day the water rises and falls again. In the lake these movements appear as currents running in and out which renew the water regularly and prevent stagnation. Water from the gulf enters the lake when the tide is high; the water of the lake runs out into the gulf at the ebb, when the level is lower. These currents, coming and going alternately, pass through the narrow passes or gates which connect the lake with the sea. With absolute regularity, these passes are crossed successively by the entering current and by the leaving current. The fish respond to these tidal impulses. Always inclined to move against the current, the fish from the sea enter the lake when the ebb leaves it and, conversely, those from the lake try to go to the sea when the tide rises. So there is a ceaseless alternation of comings and goings which, each time, carry along hundreds and thousands of fish.

This double impulse has determined the method of fishing. The passes have been barred by fixed nets made of wattle or metal webbing, and placed in such a way as to permit free entry to the lake, but not exit from it. In this manner the lake has been turned into a huge natural trap, with a superficial area of some hundreds of square miles, into which the fish from the sea come successively, and are compelled to

stay. A trap which is at the same time a profitable preserve, since the prisoners are more favoured there than in their native sea and find food and shelter ready and waiting for them. Small when they first arrive, they grow without hindrance, and, space for space, their serried ranks are more numerous and better nourished than in the sea. For the most part, therefore, catching them is a simple matter. All that is necessary is to attach to the barrier which bars the entrances, chambers divided into compartments, and into these the fish go of their own accord when they are trying to find their way to the sea.

During the hours when the current is flowing in, these fish, drawn to the waters of the sea, leave the farther parts of the lake and make for the entrances. The barrier stops them, and they go along it until they come to the opening of one of the chambers. Into it they go and, thenceforward, their doom is sealed. One after another, sometimes more or sometimes less, according to the time of year or the weather, they find their way into the final compartment and there are imprisoned. They are caught automatically, without the intervention of any man, victims of circumstance if ever there were any. The fish, shut up in a closed narrow box, instead of finding their way to the sea, accumulate in masses, without hope of escape. The fishermen have only to make the round of these chambers each day, and so gather a harvest with their landing nets. They catch masses of fish which they would never have been able to catch in any other way except with the expenditure of vastly more time and considerable difficulty. Efficient and productive fisheries of this type are used throughout the Mediterranean wherever there are similar pools communicating with the sea. They are known as crawls. That of Lake Bibans is one of the largest and best equipped. Some days a ton or more of different kinds of fish are taken from its chambers.

My trip was undertaken especially to visit this crawl, to examine it closely, observe its working, and the fish caught in it. Indeed the sight of its imprisoned fish is an extraordinary one. Collected by the hundred in a small space, covering only a few square feet superficially, but big enough to allow the fish to move about, the different species provide visible examples of all the methods of swimming they have at their disposal. These creatures, still full of life, over-excited by the effects of the current which filters through their prison net, dash about in every direction, try to find a way out, displaying an unparalleled degree of animation. The good swimmers of the open seas, sea perches, mullets, and gilt-heads, move their pectoral fins and, now and again, use their scull to give them a greater impetus. Beside them are black congers; yellow-spotted murry eels sliding about with a serpentine motion. Not far away, a few soles raise themselves to the surface by bending and rebending their bodies, then down they go again. Near them, brill, shaped much like them, but thicker and less flexible, support themselves by little movements of their marginal fins, and look like greyish plates floating in the water. The most interesting are the skate and the eagle rays, which, like birds that fly for long distances, swim by beating the water with large fins extended like wings. All these fish and others too, confined in their pen, show, by the dissimilarity of their movements, the extraordinary capacity of nature for varying its means in order to obtain the same end.

A few days later, I was to see a similar spectacle, under more comfortable conditions, and in circumstances more favourable for careful and detailed study. This was at the oceanographic station built by the state of Tunis for the study of the sea and of fisheries with the object of securing the best possible results by methodical organisation. Situated on the shore, a few miles from Tunis, it has the best possible situation

for its purpose. It is built on part of the site of the harbour of ancient Carthage, just by the old circular redoubt. The Carthaginians were hardy sailors. The sea was the source of their commercial prosperity and, at the same time, provided them with their daily food supply. Navigation and fishing were their favourite occupations. When the Romans came, they adopted the same point of view: they gave their keenest attention to the art of the fisherman as well as that of the farmer. The beautiful mosaics with which they decorated their houses often represented scenes of fishing, and depicted fishes. The importance of the fishing industry in our day is evidenced by the application of scientific study to it and by the establishment of laboratories like this station.

The station, like others of the same sort, has an aquarium, the tanks of which contain live fishes and other animals of the coast. One can examine them, observe them, experiment upon them, follow the course of their lives; they appear here exactly as they are in nature, without disguise. Through the thick plate of transparent glass, we see them moving about quite freely in the water. The largest tanks afford, in their few cubic feet of water, space sufficient to allow the aspects of reality to be reproduced. They provide, as it were, a portion of the sea which may be observed at leisure. I find most of the fishes caught in the crawl displayed in such a way that it becomes simple to find out all about them. I see them everywhere in the water, approaching, going away, sometimes on a level with me, sometimes from above, and sometimes from underneath. I can watch them turn and bend, without missing a single movement. One could not wish for anything more perfectly fitted for its purpose: here can be observed under perfect conditions all the various ways in which the different species swim.

I look, and look. Other visitors look too, fascinated by a scene so different from that to which they are

accustomed upon land. They are excited by what they see, exchange impressions, go away regretfully and are always glad to come back again. The tanks of living fish attract crowds of visitors who are certainly not specialists. The novelty delights these visitors, who now see as they are in life creatures of which they have hitherto known nothing except that they are good to eat. They can hardly tear themselves away. There is always something new to see; a change of position, an alteration in colour, re-awakens their attention immediately it begins to tire. The aquarium is a perpetual kaleidoscope, a continual attraction to the layman, a source of sustained interest to the naturalist observer.

The fish may be placed in two categories: those which are always swimming and those which swim only occasionally. The former keep well away from the sides of the tank; come and go, rise and descend, continually on the move, though their speed varies. Sometimes they maintain themselves for a moment in a state of equilibrium, but they seldom go down and stay on the bottom for any length of time. The occasional swimmers follow exactly the opposite course: they often settle; they partly cover the floor of the tank, and there stay motionless, more or less permanently, coming out of their inertia at intervals to swim for a few moments, then fall back and rest once more.

The first category, the sea perches, mullets, the sea breams known as gilt-heads, sargo and many others like them, swim with their pectoral and caudal fins. They have two speeds and two propellers, one for ordinary and one for occasional use only. Usually, they beat the water with their two pectorals like two oars, and, according to the rhythm of these strokes, their frequency and force, they move forward, either slowly or quickly, the caudal fin, in this case, acting simply as a rudder. They move in all directions, turn

sharply to one side, go up or down with an easiness, a flexibility, a continuity which nothing interrupts or alters. They even stop and remain stationary, still making use of their two pectorals, the action of which is slowed up for this purpose. But if a sudden burst of speed is required, then, as in the case of the great swimmers, the caudal fin comes into vigorous action; it acts like a scull, and pushes the body forward with a speed the pectorals alone could never give. All the deep-sea fishes are able to make use of this dual system of swimming. It is that employed by the tunny, and other related strong swimmers, and is characterized by the frequent predominance of the action of the caudal scull, and the less general use of the pectoral oars.

The fishes of the second category are more varied. If, when in a state of repose, they seem very much alike, all spread out on the bottom in attitudes determined by their particular shape, they differ and can be distinguished from one another as soon as they rise to swim. It is particularly in them that we can observe dissimilar methods of swimming. Their diversity of action in this respect is one of the most interesting features of life in the aquarium.

Among the most remarkable are the skate, the eagle rays, and the electric rays or torpedo fish. We see them lying on the bottom, their wide bodies outspread, looking more or less as they look on the fishmonger's slab before being cut up for sale. The only sign of life is the movement of their bulging eyes, or that of the respiratory organs. We are surprised when they move and get ready to swim. Then they rise and, agitating the extended sides of their bodies, use them to beat the water as a bird uses its wings to fly. There is no better word than "flying" to denote their manner of swimming. But how much more flexible and elegant is their swimming than the flight of a bird! In the bird the wing is a dry, hard limb, covered with

solid, resisting feathers, necessarily so in order to exert pressure on the air. Only the beauty of colour relieves its rigid appearance. The wing of a skate swimming is much more attractive. Composed of an enlarged pectoral fin, attached all along the side of the body and head, it waves and bends as it rises and falls to beat the water. Its movements are elegant and graceful. The edges form a sort of festoon as the fish goes along. The creature thereby adopts a pleasing attitude, which strikes one as definitely remarkable. There is nothing in the position of rest which would lead us to expect anything like this.

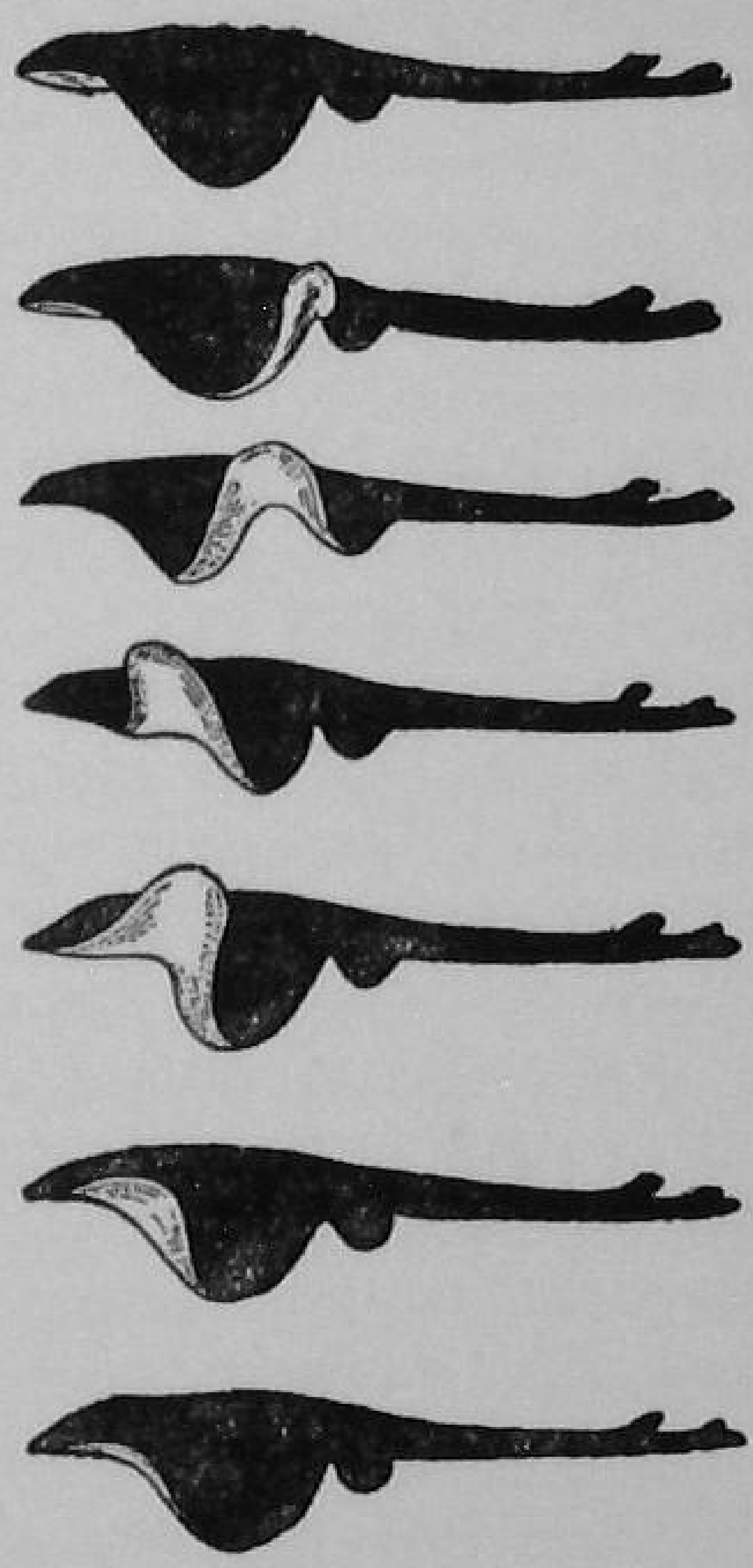

FIG. 11.—Successive stages in the movements of the pectoral fins of a skate swimming. (From Marey's chronophotographs.)

The skate, large or small, move about the tank in this way, sometimes nearly filling it with their huge "wings" in action, sometimes lying inert upon the bottom. The smaller ones often cling to the glass side and, with pearly white, slightly rose-tinted, bellies, somewhat resemble clock faces. The two pelvic fins, with their claspers oscillating about their point of attachment, seem like the hands, and the vertically hanging tail, the pendulum. The others, stronger and heavier, rest by stretching themselves along the floor of the tank. At times they start off swimming one after another or all together, and finally settle again. Each species, according to

the strength of "wing" it possesses, has its own length and kind of flight. Some are more favoured than others; and the most active, the best equipped among them, are the eagle rays.

They have an extraordinary appearance, even for a skate-like fish. Their snub-nosed head, with large eyes and the muzzle of a batrachian, attracts attention by its unusual form. The wing-shaped fins strike one by their extent and contour lines. Very full, with a spread almost twice the length of the trunk, they stretch backwards and end in a point like the wings of a swift-flying bird, justifying the names "sea eagles" or "sea hawks" by which they are sometimes called. But these names are only half deserved. If the resemblance of the wings is responsible for their adoption, there is absolutely no resemblance to the bird as regards the beak. The eagle rays have a slit-shaped mouth, with large flat teeth, set close together like paving stones, and capable of crushing hard objects. They are incapable of seizing living prey which can defend itself or get away. Beasts of prey, eaters of flesh they certainly are; but to the detriment of the shell-fish which lie on the bottom, whose calcareous envelope they crush with their jaws, to find inside the nourishment they seek. For this reason they are feared by oyster-farmers, who regard them as dangerous enemies against whom measures must be taken, for they penetrate the oyster beds and destroy the oysters which are placed there.

The skates and the eagle rays are not the only fish which are able to use their pectoral fins to move and swim as the birds fly. The gurnards do the same, although in a different way. When I was dealing with fish that walk, I referred to the strange appearance of these creatures, which rest on finger-like parts of the pectoral fin, and even walk along the bottom with their help. But they also swim, and for this purpose use the remaining part of the fins which are spread like broad

oars. These fins have not the suppleness or the undulating grace of those of the skate; they are narrowly jointed to the body instead of confluent with it, supported by ribs which stand out and are quite stiff. Their only advantage is their fullness, which allows of their being used as paddles and, in certain species, the variety of their tint and the beauty of their colouring. Compared with the skate's fin, the tool is of the same type, but made on an entirely different plan.

The flying gurnards follow this model, but in an exaggerated way and in another respect. They sometimes settle on the bottom, but more often they swim about in the water of the tank, using their tails as sculls, and forcing their way to the top. As they approach the surface, they spread their pectorals, which are broader and longer than those of the typical gurnards, since, when fully extended, their combined spread exceeds the length of the body. They extend these fins, but they cannot use them effectively as swimming paddles, because they are too big for the muscles which activate them. The resistance offered by the water—the arm of the lever being too long—exceeds the power of the motor. These unusually broad fins are not much use as propellers through the water because of their very size; at most they serve as balancers in the water, the sole propeller being the scull formed by the tail. We may observe, however, in the fishes' behaviour under water the preparations for their planing flight when they succeed in lifting themselves above the surface. They give the first impulse by vigorous strokes of the caudal fin, shoot obliquely upwards from the depths, spread their pectorals as great flat balancers and, coming out of the water, are carried on by the speed they have already attained, and are held up in the air by these balancers which act as planes until the force of gravity brings them back into the sea from which they sprang.

In a corner of the tank a few seahorses with pre-

hensile tails are clinging to a support. Sometimes, one of them gets loose, and, gently, in its extraordinary upright attitude, or leaning a little over, progresses through the water with a sort of gliding motion. It uses only its pectoral fins. Though small, thin, transparent, in fact hardly visible, they are active and effective, even if not very powerful. They are an example of the least developed and perhaps rarest method of swimming in this way.

The methods of swimming, above described, namely by means of the tail or the pectoral fins or both combined, are the commonest. But there are others. Sometimes the pectoral, the pelvic, and caudal fins are altogether absent or so small that they are useless. Then we find other machinery for swimming, other methods which still further increase the extent of the series of differences.

Beside the skate, upon the bottom of the tank, we find lying flat-fishes of a different kind, soles and brill. Usually, like their neighbours, they stay there without moving, stretched out, giving signs of life only by the gleam in their eyes and the movements of their breathing. But, occasionally, they move and change position, either by swimming, or by gliding, climbing over the bottom. Not, like the skate, able to use their pectoral fins, which are too small and unsuitably situated, or their tiny caudal fin, they employ the body itself and their unpaired fins. The dorsal and anal fins, surrounding almost the entire trunk like a sort of collar, beat the water with a wavy motion and so provide an impulse, which though not of any great strength, still produces the desired effect. If the body is heavy, as in the case of the brill and the turbot, the fish swims slowly and only for a short time; if it is more pointed, finer, as in the case of the flounder, plaice, and dab, it gets along better. Finally, if the fish is more pliable and longer, like the sole, the body itself gives the required impulse. It bends over

in the water and back again, undulating like an elastic blade, finding within itself the secret of its movement, and so goes forward. It does not go very far, and soon falls back; but, each time, it covers several yards in a few repeated undulations, and has only to begin over again to cover a considerable distance.

Other fishes, of very different shape, act in the same way, using their bodies directly. Such are the eels, congers and murries, long, snake-like, flexible and undulating, able to crawl over the bottom and to swim in mid water by the same means. Here and there in the tank are heaps of pebbles and debris, with spaces between. Several large congers with dark shining skin have taken up their abode there, and are almost completely hidden, only their necks and watchful eyes protruding. Occasionally one or other of them leaves his shelter. His long cylindrical body comes out by degrees, then he begins to swim. He moves forward with a serpentine motion, winding his way through the water, exhibiting an elastic suppleness, an elegance of which snakes on land are incapable. So he progresses easily, swiftly, moving his great black body everywhere, poking his nose in all directions, then returns to hide again. Sometimes he seems to hesitate or stop, then, to keep himself up, he uses his median dorsal and anal fins only. They fold and contract along his whole length. Then he goes on his way, continuing his pliant movements, the harmonious twists and turns of the serpentine mode of swimming of which alone he is capable.

These methods of swimming, numerous and varied as they are, become even more so when we go beyond the fishes to consider other aquatic animals, their fellows and companions in the world of waters. Organs and means are multiplied almost indefinitely, and all end in one definite action, movement by swimming. The tank, in which I am making my observations, contains, besides its other inhabitants,

two sea-turtles known as logger-heads, common enough upon our coasts. Living well out to sea, near the fish upon which they feed, they are sometimes caught in the fishermen's nets. They live quite comfortably in an aquarium, for they are marine reptiles with lungs, and breathe air. Their general shape is like that of the tortoises of our gardens, but they are built on a larger scale. Their carapace is thick, but not so domed; their mobile head armed with a blunt beak, but stronger. But the limbs are different. In place of the short, massive, column-like paws to which we are accustomed, which give to the land tortoise that heavy slowness which has become proverbial, the marine turtles have long, firm, scaly fins, which they use very effectively. Their four limbs, both front and back, especially the former, are powerful oars, which impel the body, in spite of its massiveness, swiftly and continuously. These turtles are among the finest swimmers in the sea.

It is easy to see how they progress, and their movements are worthy of attention. The front, or brachial, limbs are larger than the hind limbs, and do the most work. If, as regards situation, their nature as front limbs, and function, they correspond to the pectoral fins in fishes, they differ from them by a better articulation with the shoulder, conferring greater mobility. They can turn in every direction, on their area of attachment. When the animal is swimming, it begins by bringing them forward and joining them in front of the head, like a swimmer preparing to dive. It then sweeps them back sideways, extends them to their full length, presses the water with their whole surface, and prolongs their movement to its extreme limit. Their tip, in a displacement of such magnitude, describes almost a complete half circle. Stronger and better placed than their counterpart in the fish, they do their work more effectively.

Near the turtles, in the tank and swimming not far

from them, though trying to avoid them as far as possible, are animals of a very different type. These are the cuttlefish or sepias which, in the natural classification, come among the Cephalopod molluscs, near the poulps or octopuses and squids. I have already referred to their bodies enclosed in a cloak which looks like a bag, and the possession of an un-

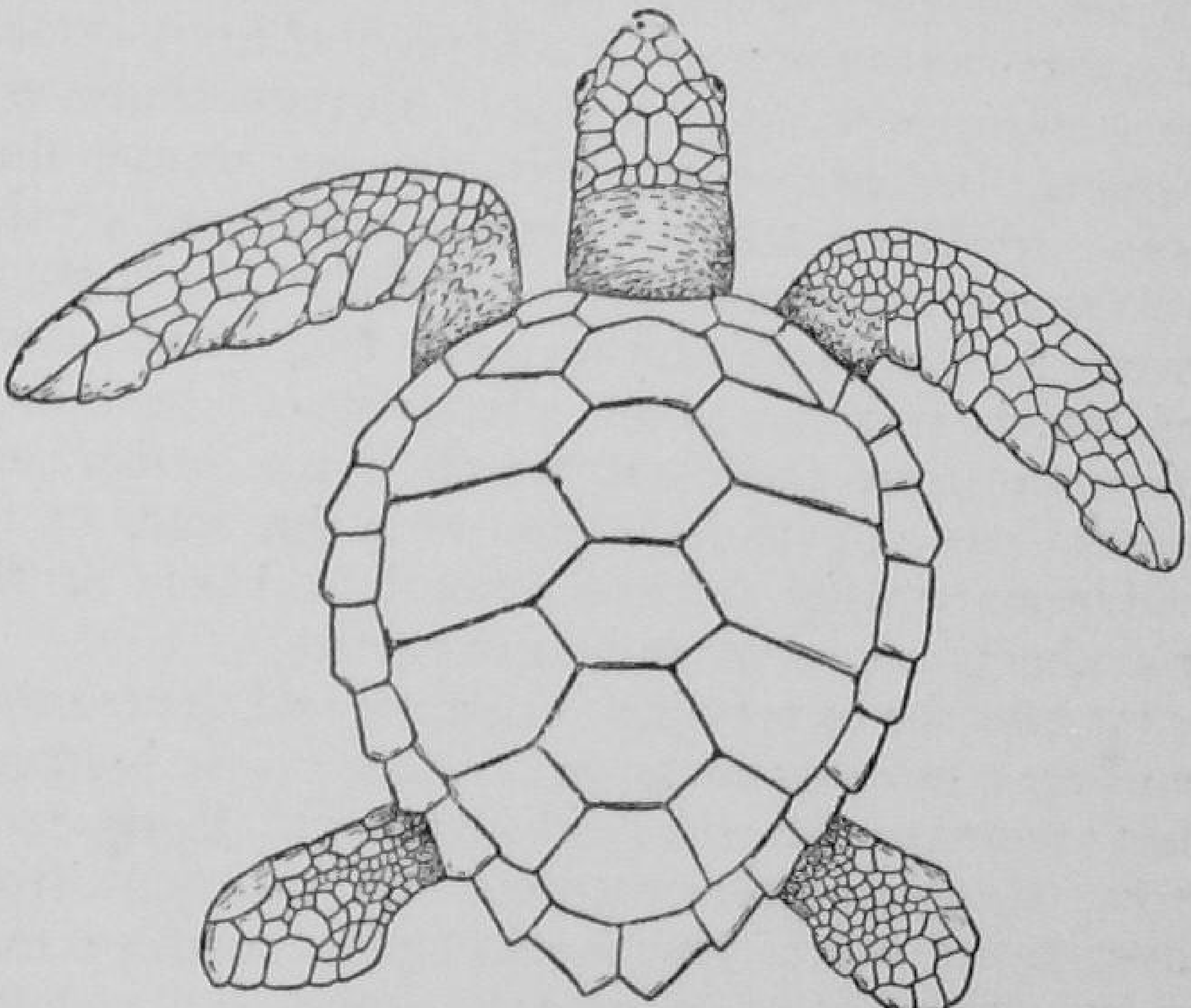

FIG. 12.—The Loggerhead Turtle. The animal may be as long as three feet or more, and weigh over 200 pounds. It feeds upon fish and squids.

dulating membrane on the sides which enables them to swim and thus gives them a curious resemblance to the flat fish. They have, further, greater speed and an additional means of progression. If we touch them with the end of a stick in this tank in which, hitherto, they have remained suspended without movement, we see them shoot suddenly backwards, with a movement of withdrawal, the tentacles trailing in the opposite direction; then they pour forth their ink, a thick black liquid which spreads around them like

a cloud. In this case, the propeller is a short pipe, the "funnel" justly so-called, wider at its base than at its point where it opens outwards, while its base communicates with the cavity left between the bag-like cloak and the body. In the normal state, this space is filled with water which comes in through the wide opening and bathes the gills by which the cuttlefish breathes. When it takes to flight, it closes this entrance and so imprisons the water it contains; then, the cloak contracting vigorously, this water is expelled through the funnel, the only way in which it can escape, and, violently forced out by this means, produces a swift recoiling motion which drives the body briskly backwards. This extraordinary method, which is unknown in fishes, is also that of the poulps when swimming, and of the arrow-like squids which, living in the open sea, regularly and continually move in this way.

This examination of the other inhabitants of the tank shows us new and unexpected aspects. It accentuates the impression of diversity which the fish, considered by themselves, had caused; this increases when it is extended to other creatures. Occasionally, we have an opportunity to fish up the bell-shaped jelly-fish and watch their method of swimming; their progress, which is not very rapid, is practically limited to keeping themselves up, but there is, besides, a definite move forward, effected by sudden contractions of the circumference of the bell. Then again, we may see the beautiful Ctenophores, whirling about like massive or striped ribbon-like jelly-fish, made of a transparent or very slightly rose-tinted glassy substance. These creatures swim by beating the water with little flappers like the teeth of a comb, set out along the body in eight radiating bands. Among the inert shell-fish lying on the bottom, we may even see some of them, like the little scallops or pectens, suddenly get up, perform a series of little leaps, beating the water with the two valves of the shell,

which they bring together and then quickly separate like the two plates of a pair of castanets. And if our vision were still further extended, if the eye were able to discern the microscopic animalcules which populate this water in numbers at least as great as those of the larger creatures, we should see those organisms, of minute size, move about like the rest, swimming by methods appropriate to their structure, and beating the water with the delicate little oscillating filaments, called vibratile cilia, with which their bodies are covered, either entirely or in part.

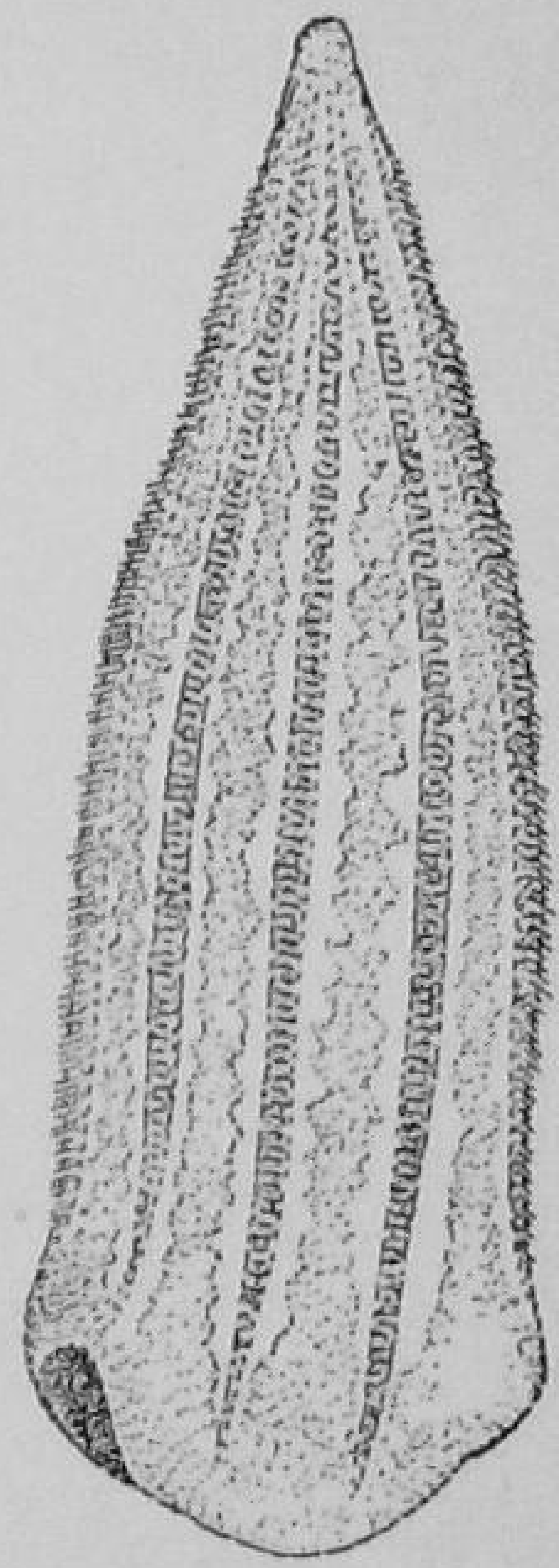

FIG. 13.—*Beroe*. The animal, a ctenophore, or comb-jelly-fish, supports itself in the water by means of its movable flappers in rows, which may be up to four inches in length.

These repeated observations lead to a definite conclusion. The inexhaustible diversity of the means which life employs fills us with astonishment. For a single functional action, swimming, Nature works out and reveals to us an incredible wealth of different processes. All sorts of devices are brought into action. Every organ is utilized, even those we should least expect, or part of an organ at any rate. But if we take account of this diversity alone we shall have an incomplete idea both of Nature and her power. The tank in our aquarium, despite its variety and the pleasure it affords us, gives us only a small-scale representation of what is going on, freely and on a far greater scale throughout the immensity of the world of waters. It gives us a glimpse of the life in those waters, but by no means of all life.

Beyond its diversity, Nature displays its equally remarkable multiplicity, its prodigious abundance, of life. We must seek that out also, and find it, if we are really to know things as they are.

While watching, through the glass wall of the tank, the goings and comings of the animals imprisoned there, I have sometimes reflected that, in spite of their number, if they were all taken out and piled up in a heap, they would hardly fill an ordinary sized basket. Then I have remembered the great trawls used in the Atlantic Ocean, in which the net, after dragging along the bottom for several hours three to six hundred feet below the surface, brings up tons and tons of fish and other animals. When the net is opened, it lets loose upon the deck a flood of all these captured creatures. The fishermen fill huge compartments of the hold with them. We see, still moving, as in the tank, skate, turbot, gurnard, not in ones and twos, but in hundreds. Yet the net has only dragged a mile or two over a space about thirty feet wide. This space, inconsiderable when regarded in relation to the immensity of the sea bottom, was sufficient. The net seized this mass of creatures, and its contents give us an idea of what subsists and lives on the bottom, or not far from it. The fecundity, the diversity, the richness of these lives surpass anything we can contemplate in our own world. The life that exists far from our sight is out of all proportion to that which we see around us.

But we can get an idea of all this life by the help of various individual observations made in our scientific studies, completing them by a system of contrasts and comparisons. The picture of the flat desert, desolate beneath the burning sun, returns to the mind. The space dragged by the trawls is also an immense plain, a vast, flat, horizonless area, covered with soft mud as the desert is covered with fine sand. Only, instead of light air, it is surmounted by a thick sheet of water;

instead of blazing light, the light is at most faint and subdued. If we were able to go down and explore it, our eyes would see no distance, our ears would hear no sound. Yet in this obscurity, in this silence, beneath the water, life exhibits an intensity of action greater than anything we could have imagined. Instead of being a desert, it supports a tremendous realm of abundance and activity.

Our minds may perhaps construct for us what the eye cannot see. They can discern in this eternal dimness a spectacle which makes no appeal to those who take part in it. The plain of mud may bear, here and there, tufts of dead coral like the dry sparse shrubs of the desert. In it contractile soft polyps implant themselves, forming clusters simulating living vegetation. Shellfish which remain permanently in one place or move very little, sea-urchins, and star-fish, though more varied and numerous, remind us of the small terrestrial animals of the surface of the soil. Here and there crabs, poulps, molluscs crawl or walk. The congers, and the other fishes of their group, pass with their undulatory motion like serpents on the sand, or hide in their lairs. Skate, lying on the bottom, rise now and again to flap along with their fins, much as eagles and hawks go through the air. Like them the gurnards swim with their beating pectorals. Then above this population of the sea bottom, at different levels all the way to the surface, the open sea fishes live and move in all directions, the jelly-fish, and countless floating animals, alone or together, swimming, swimming all the time, filling the sea with an intense life which has no counterpart on land.

We may well be surprised by the contrast. After such a journey to the sea, the air which surrounds us, the soil upon which we stand, seem poor and empty. The word "fecundity" takes on a new meaning, greater than that which it has around and above us. Life itself acquires a new significance. This gloomy

empire of the sea, far from being solely a realm of death, is, on the other hand, a place in which living activity is displayed in an unsurpassed degree. We understand the mistakes into which we are easily tempted to fall. We form too many conclusions by considering life in our own image. Life is not necessarily bound up with the light and heat which surround us, which we cannot do without. It is vaster, more extensive than we commonly imagine. In many ways it escapes our direct observation. It has its inaccessible attributes which we imagine rather than perceive. The more remote, the more secret, the deeper they are, the more strongly do they impress.

CHAPTER IV

THE FISH OF BOUILLABAISSE

THE word "bouillabaisse" invariably makes us think of Marseilles. It calls up a memory of that active city on the shores of the Mediterranean, and of the bright sun of Provence shining down upon its girdle of harbour, piers, factories, and warehouses. That delightfully odorous dish, perfumed and coloured by saffron, that "soup of gold," "bouillabaisse," originated there, and from there has spread throughout the world. It is prepared and served today in Paris and Algiers, in London and San Francisco. Wherever fresh fish is to be had, it is always possible to enjoy the characteristic slices of bread, impregnated with the smell of the sea, sprinkled and gilded by the saffron liquid. Its fame is universal. And, now, it is to be had everywhere.

True, say the epicures who have travelled, there is no great port where bouillabaisse is not to be had, or at least where one cannot have it prepared. But, nowhere has it the flavour which we enjoy at Marseilles or Toulon; in no place, whatever the tastiness and freshness of the fish of which it is composed, does it give out that peculiar aroma, that delicate, enticing perfume of the seashore, so admirably enhanced by that of saffron and other condiments, which we relish so much on the coast of Provence. There it possesses a peculiar element which is lacking elsewhere. As, in order to be perfect, it calls for an unusual variety of fishes, doubtless, say the connoisseurs, one does not get the same assortment elsewhere. Fish can be cooked in a saffron bouillon

anywhere, but only at Marseilles or the country near by do we find the finest bouillabaisse, just as only in certain special parts of the country are we sure of obtaining wines of the finest vintage.

There is a certain element of truth in such remarks. At Marseilles it is only necessary to go round the fish shops and pick out the indispensable assortment. There is no difficulty about this, for the assortment is known as "bouillabaisse fish." We see, lying among the ribbony leaves of seaweed recently gathered and damp to keep them fresh, the different kinds—always the same kinds—of fish which make up the dish or provide its basis. First the hog-fish, or scorpion fish, with large spiny heads, the body marked with dark brown, russet, and bright yellow; the sea bream, striped with red, orange and blue, like flags; the variegated sea-perch; the wrasse with spots of all colours; the black, elongated congers; the sargo or silver sea-bream, and several others, graced by crabs, mantis-shrimps, and small crawfish or spiny lobsters. From this varied collection, spread out upon its bed of algæ, there rises a penetrating odour, that of rocks washed by the sea, the same odour that one breathes on the seashore, but stronger and richer. It is precisely this which gives its charm to the best bouillabaisse. No other quality of fish or other sea animal would do it so well.

The epicure is satisfied with this explanation, and looks no further. The naturalist wishes to know more. He asks where these different kinds of fish live in their natural state, whether they are found together, or whether they are widely scattered. He would like to know whether this miscellaneous combination presented on the fishmonger's counter is made by the fishmonger himself or if it is a natural arrangement. A little investigation will soon provide the answer. This is a natural combination. Neither the fisherman nor the fishmonger prepare it. All

they do is to catch and sell the fish as the sea, in certain places, makes provision.

All over the Mediterranean, on the coast of Provence and elsewhere, the shore, when it is not covered with mud, supports at a depth of from ten to fourteen feet, sometimes forty feet, the growth of a peculiar plant, the grass-wrack, which flourishes and multiplies near the algæ. These vegetables, belonging to the class of monocotyledons like grasses or palms and far surpassing the algæ as regards complexity of organization, are able to live beside them in the salt water without ever reaching the air. They make up a family in this class, that of the *Zosteraceæ*, the Provençal species of which is technically known as *Posidonia caulini* Koenig. In all favourable places this plant covers the bottom, buries its root-stocks in it, and outspreads vertically in the water its long flat green ribbony leaves, forming with them a sort of submarine pasture affected by changes of season, just like the vegetables which grow on land. Under the water, it comes up in spring, flowers, then the leaves lengthen and are dropped in autumn, just like those of the trees in our forests, becoming green again the following spring. These dropped leaves, driven always nearer to the shore by the waves, accumulate in the coves by the water's edge, and there dry, forming thick carpets on the shore which are used for various purposes. Yellowish balls of massed filaments are produced by the action of the waves felting the hairs and rhizomes. The vegetation of the sea bottom, conserved by the salt water, is prevented from rapid decomposition and so devoid of the objectionable elements involved in that process.

The fishes that are used for bouillabaisse live in these plantations of grass-wrack, just as land animals live in bushes and thickets. Few and far between when these plantations are small in extent, in those districts, for example, where the shore rapidly falls

to a considerable depth, they are more frequent where the plantations are greater, as in the neighbourhood of Marseilles and Toulon, where the depth which suits them is maintained for great distances. They go thirty, sixty, a hundred feet down, seldom more. These favoured places are covered by vast bushy prairies, in which, under cover of the closely packed vegetation, among the leaves, the particular kinds of fish which frequent them increase and multiply to their hearts' content. In such places they are very numerous and are most easily caught. The fisherman has only to take them; the assortment is made for him, all ready for sale, and he has no reason to make any change in it.

The fish are caught in several different ways; ordinary lines, ground line nets, put out in the evening and taken up in the morning, are both used. The gear principally chosen, the use of which demands consummate skill, is a drag net, a trawl attached in a peculiar way to a rod. In the local patois it is called "gangui". It consists of a cylindrical net, measuring about twelve feet long and from six to nine feet in width, of which the opening, supported on a framework of iron bent in a semi-circle, is fitted with two wings held apart by a rod placed transversely. Two cables are fastened, one to each end of the rod, and these are spliced so as to form one main cable which goes right up to the fishing boat and there is made secure. The fisherman, with a sailor to help him, casts his net until it touches the bottom, and then sets sail. The wind drags it along the field of grass-wrack. Everywhere it touches, the majority of the creatures which happen to be there are encircled by the wings and finally brought into the net. When sufficient time has elapsed, the fisherman has only to pull up his net to find at its bottom, in the required proportions, the assortment he was looking for.

On several occasions in different summers, I have taken part in this operation at Marseilles. Today it

is not so common. It is a method of fishing particularly interesting to the naturalist; it enables him to secure all sorts and conditions of material for study in the net which is brought up from the sea bottom. There is always something of interest to him. I remember the things which happened almost as clearly as if it were yesterday. I remember the strong boat, its brown hull, its yellow deck and thwarts, its big white triangular sail. I see the fishermen, Armand the skipper, with sturdy, energetic face, grey bristling moustache, and strong, thick-set figure. A Marseillais of an old family, descended from generation after generation of "gangui" fishermen, he was passionately devoted to a job which he knew from A to Z. I see, too, his sailor, Narcisse, known as "the Neapolitan" from the place of his origin, untidy, big-bellied, obliging, active when activity was called for and slack the rest of the time, his head carefully shaved. With his arched nose, nut-cracker chin, and round eyes, he had a most extraordinarily merry face, just like Punch's.

It took the whole day. We set out at dawn, almost before it was light. At this early hour, with a gentle land breeze, we set sail and slowly made our way out of the harbour into the gulf. Frequently there was an almost diaphanous low mist lying over the water, which softened the distances but accentuated things that were quite close; the sea seemed more transparent and more limpid close to the shore. Then the sun came out. As it rose higher in the sky, it dissipated the mist; daylight spread over the sea; the land breeze weakened and finally fell, and we came to the islands Pomègue and Ratonneau, which stand out in the middle of the gulf like outer guardians of the harbour. Between the limestone cliffs we sought a cove, a little sheltered creek, a "calanque", to use the local word, where we might wait until the time arrived to begin our fishing.

We had not to wait long. There was a short period

of calm when the land breeze fell, but soon the sea breeze came up in its turn and rapidly freshened. Blowing in the opposite direction, salt-laden, brisk, it brought us the healthy smell of the sea and the freshness of the open waters. We left our shelter, set sail again and made for the fishing ground over the grass-wrack field; then cast our "gangui", gave out rope until the net was exactly spread over the bottom and, with the wind behind us, began to trawl.

According to the weather and the place, we would trawl for an hour or two. While this was going on, and in order to get the best possible results, Armand used to try all sorts of different manœuvres. He would watch the coast and take bearings so as to know the course the net was taking, and avoid catching on wreckage or rocks he knew. He would change the set of the sail so as to keep the boat on the proper course, as it drifted before the wind. He would pull on the rope attached to the net to judge whether it was dragging along the bottom, or if it had been lifted above it. He and his sailor dashed about the boat from bow to stern. He had an eye for everything, and kept a look out for the elements, wind, sky, and sea. Occasionally, he would call me to show how the resistance of the net tightened the rope attached to it. Then he would curse the wind because it was not strong enough for his liking and reproach it for not blowing hard enough to put out a candle. His eyes, his lips, his hands, were never quiet.

Then it was time to stop trawling. We clewed up the sail and pulled up the net, a little at a time. Since the load was heavy, this was no easy task, and we all took a hand.

The different parts of the tackle appeared one by one, first the cables, then the rod, which we detached, the two wings, and, finally, the net itself. As it came up, Armand, leaning over the side, shook the meshes,

making anything that had happened to catch in them, fall into the bottom. At last that bottom appeared, swollen and distended by its contents, which we could see through the meshes, strips of seaweed, fluttering fins, glittering scales, the waving tentacles of poulps. A final effort brought the well-filled net out of the water, carried it over the side, and deposited it upon the deck. Armand unfastened it in a place previously prepared, and the whole contents poured out and spread over the planks of the deck, creatures of every shape and form and size, of every conceivable colour, mingled with the broad green seaweeds, and long narrow leaves of grass-wrack which the net had caught and brought up.

The first thing which strikes us, and the most remarkable, is the mixture itself. We do not expect to see such a mass of creatures so different one from another. The first time one has this experience, and even after becoming accustomed to it, the result is still astounding. Another surprising thing is the strong odour exhaled by this assemblage of plants and animals, an intense, exciting, iodized, ozonated, phosphorated odour. It is similar to, but much stronger than, that of rocks beaten by the surf, it is that of the bouillabaisse fish placed on sale in the market-places. Here we breathe it, we have it at its very source, without mitigation, gripping nose and throat at the same time, almost nourishing, and capable of being tasted, so strong it is in these circumstances.

When the net has been emptied, the sail is set again, and we go back to the creek from which we started. The boat speeds through the water now that it is freed from the resistance of the net. Armand, keeping his place at the helm as a skipper should, watches the incidents of the trip. I, with the help of Narcisse, sort the catch and set them out according to their nature, the fish in a large wooden tub, the other animals in glass containers, for later study.

These fish do not differ in the least from those of the shops; they belong to exactly the same species. But, now, they look somehow different, and give a better idea of what they are really like. Full of life, jumping all over the place, their colours are clearer; they look fresher; their contours are more natural. The crawfish or spiny lobsters of different kinds beside them show, by their vigorous leapings, the degree of life that is still in them. The crabs career about in all directions, or hide under the bunches of seaweed. On the boat which has just caught them, the assortment which is inert and discoloured on the shop counter is animated, brightly hued, full of movement and life.

But the naturalist is inclined to pay more attention to the other, still more numerous, creatures which come with the fish and live near them in the submarine field. The professional fisherman throws them away, for, since they cannot be eaten, there is no profit to be made out of them. The naturalist takes and preserves them for purposes of study. Their diversity, the way in which they are found associated, their appearance—all these combine to form one of the most remarkable phenomena of nature.

In the first place, for they catch the eye in the miscellaneous assortment brought up by the net, are spherical or oval bodies, sometimes as large as one's fist, compact in appearance, and of a splendid orange colour. It is especially from them that we get the powerful odour of the sea which the catch as a whole gives off. They are inert, and when we pull them apart with a finger, we find a felt-like, resistant flesh, which is almost homogeneous except for a fairly broad opening pierced in a particular point of the surface. These are globular sponges, containing a delicate skeleton of siliceous concretions which makes them practically useless. Their scientific name, *Suberites*, expresses the similarity of their flesh, as regards its

consistency, to a piece of cork. The orifice we mentioned leads to a channel which ramifies in their tissue and serves as a shelter to a hermit-crab, which finds in this way the protection its soft abdomen needs. They act, in fact, as a sort of travelling house for it. This hermit-crab, which looks like a cray-fish, lodges its abdomen within the sponge, and, although the sponge is much larger than itself, it carries it about and takes it along with it quite easily, the density of the water allowing these aquatic creatures to perform such *tours de force*. You can imagine nothing stranger than the sight, in the tank to which we have taken it, of the little hermit-crab armed with its nippers carting about its enormous house, moving it without the slightest difficulty, then, at the least sign of alarm, stopping, and retreating completely into it, so that the enemy can find nothing to attack but this quiet, simple-looking house.

Hermit-crabs of different sorts are to be found in the thickets of the field of grass-wrack; there they take the place of the insects which infest our shrubs, quite as many in numbers and just as industrious. While some find shelter in the large sponges, others are content with a simple shell. Others, again, fasten themselves upon a still more remarkable covering; they associate with the sea anemones with stinging tentacles, clothe themselves with them for protection, and so move about, bearing their companions with them like the blind man of the fable carrying the paralytic.

Here and there, cuttlefish, still full of life, extend and twist about their long, arm-like tentacles, clinging with them to anything they can get hold of, squirting out black liquid whenever they are touched. Besides the smell of the sea which all these creatures have, they give out a musk-like odour, stronger in a certain species, which is consequently known as the musk-poulp.

These moving creatures and others, crawling worms, shrimps, and a host of crustacea of different sorts, move about in disorder in the heap of which they form a part. Others, less active, even inert, lie beside them. We pick up a sea cucumber or trepang, which looks like a black pudding, and feel it palpitate as we take it into the hand, and contract with so much force that it expels through the mouth almost the whole of its digestive tube. Next to it are large sea-urchins, spiny balls of different colours, black, brown, purple, light yellow, or mottled with white or violet. Not far away, we see with their five radiating arms, star-fish, of different colours, most a blazing vermilion, such as no painter or blossom could ever hope to equal. Branching corals, blocks of seaweed incrusted with lime and hardened, brought up from the bottom where they occupy the spaces between the grass-wrack, bearing, either on them or in their crevices, transparent sea-squirts like diaphanous jelly; shell-fish and other animals, as many as they are varied. The field of grass-wrack, beneath the mass of water, reveals itself as a realm of intense life, prodigious in its diversity and abundance, of which nothing about us can give us the faintest idea. We obtain this idea, create it within ourselves, only by considering the product of this fishing. So we reconstruct a strange, surprising, almost startling world, which surpasses our powers of imagination.

We may have in fleeting glimpses a direct vision of this world. While we are engaged in our work of sorting, the boat nears the shore; the bottom of the water comes nearer, and we are able to see it better. The sunlight, almost vertical now that it is nearly noon, sheds a bright light upon it. The surface of the sea, motionless beneath the shelter of the cliffs, allows our glance to penetrate right to the bottom. Leaning over the side, I see below me tufts of grass-wrack, with long upright leaves; they cover the

bottom like a forest of shrubs. Between them, on rock and gravel, I perceive some of the largest of the creatures which live there. Occasionally, a flash of silver betrays the swift passing of a fish. A strange countryside, which transposes into the water, with other shapes and other attitudes, the general effect of our own landscape. Plants with upright leaves take the place of the shrubs; seaweeds represent the mosses and lichens; fishes replace the birds, and crustacea the insects; animals unknown on the earth, sea-cucumbers, sea-urchins, starfish, corals, shell-fish, sea-squirts, complete the picture. But, if the structures are different, the arrangement is not, and the leaves of the grass-wrack cover everything as those of the trees overshadow the life of the forest undergrowth.

The submarine prairie has a definite condition of its own which this resemblance brings out the more. It has an appearance of its own, or, if we use scientific language, its own "facies". It contains within itself an association of animal life which exists in it and nowhere else. The fishes and their companions have no counterpart elsewhere. Its fauna has a special character which becomes clear more easily than in most other regions or other facies of the marine world. In it we see clearly that aquatic creatures, like those which live on land, far from disseminating themselves without regard for order or regularity, form themselves into groups in accordance with their affinities and needs. They form localised populations, and each one has its place in that population and lives its own life in it.

Meanwhile, our boat is coming into the creek, and it is time for our last occupation before returning to port for our meal. Our appetites, stimulated by the tasks of fishing and sailing, excited by the salt sea tang, demand immediate satisfaction. Bouillabaisse, made of the fish caught in our "gangui" and still jumping about in the tub into which we put them, is

to be our main dish. As soon as the boat was moored, Narcisse brought on deck the little brazier on which we should have to cook, put into it coal and kindling wood, lighted it and leaned over it, blowing as hard as he could to make it blaze. When the fuel had caught, he got up, fixed up a portable table, set on it our modest, but unbreakable, tablecloth of tin and hammered iron, then finished the job by spreading over our heads a sail to keep off the sun. Armand, the skipper, now turned from a fisherman into a cook, cleaned the fish, washed them in the pure sea water, and cut them into large slices.

When he had finished, he put everything into a pot, added as much water as was necessary to make the liquor, with all the essential condiments, not forgetting the saffron, and set the pot, now full almost to the brim, on the stove, carefully covering it with an old lid. Then, leaving the first stages of the cooking to look after themselves, though he kept an eye on them, he cut some broad slices of bread and put them at the bottom of a bowl. The water in the pot soon began to simmer, then to boil. From between the pot and the lid there escaped a steam, not very much to begin with, but soon thicker, and its aroma would have excited our hunger still more if we had not reached the very limits of appetite. Armand allowed the boiling to go on for four to five minutes, then got up, took off the lid and, with a wooden spoon used only for this purpose, carefully scraped the thick, mucilaginous crust which had formed on the sides round the steaming liquor, put it back in the middle again and mixed it up with the liquor itself.

"This crust is the juice of the bouillabaisse," he said. "Almost all the aroma of the fish stays in it. If we left it stuck to the pot, we should lose it, and the bouillabaisse wouldn't taste half so good."

As I watched him at work, I tried to explain to myself as a naturalist the actual use of this little opera-

tion from the epicure's point of view. This crust, to use his own expression, was nothing but the mucous juice extracted by the liquor from the skin of the fish and coagulated by the heat. This juice, made out of the skin itself, is strongly impregnated with that smell of the sea which we find so strong in the catch brought up by the " gangui ". As it is this scent which gives bouillabaisse its particularly attractive aroma, the juice which produces it is therefore very important and every effort should be made not to lose the least drop of it. There was good reason for Armand's spoon. I understood why the hog-fish, of all other species, has the reputation of being particularly valuable. Its stubby body and large thick-skinned head have a greater proportion of this highly valued juice than anything else. So the idea of the " facies " is extended, going beyond the habitat, even to sensations of taste and smell.

These reflections only lasted a moment. Hunger, made all the keener by these preparations, now had the mastery and claimed obedience. Soon the bouillabaisse was ready, Armand took the pot with both hands, poured the golden, perfumed liquor which came from it over the slices of bread, put the fish in another bowl, and set the lot on the improvised table. So we finally assuaged our appetites and satisfied our taste for good living at one and the same time. The sky full of light, the brilliant rocks, the sparkling sea, surrounded us with gorgeous colouring. No dining-room, however magnificent, could ever hope to equal this natural splendour.

After the meal, before starting for home, we were glad to chat as comrades happy at the termination of their common day's work. I have a very high opinion of the conversation and character of fishermen, as, in another field, of those of mountain guides. Both are moulded by the hard life they lead, which keeps them continually face to face with the great scenes of nature,

makes them accustomed to perpetual danger, and obliges them to mutual sacrifice. In this way they develop independence of character, practical common sense, and qualities of coolness and firmness which one rarely finds in combination elsewhere. Their conversation is often in advance of their appearance and mode of life.

One day I said to Armand, the skipper: "Have you any idea where the word 'bouillabaisse' comes from? I have heard and read a great many explanations, but they all seem to me to smack too much of the pun. The absurdest is that which attributes its invention, in a time of fasting and penance, to an abbess called Bouille who is supposed to have found fish simply cooked in water too tasteless for her liking. Another alludes to the idea that one lets the fire down (*abaisser*) when the liquor in the pot begins to boil. Now I have often watched you, and you don't let the fire down in the slightest; you even stoke it up so that the boiling shall not slacken. The word must have had another origin."

"I am only a fisherman," Armand said. "I can read and write, and just about manage the first four rules, and that's as far as my studies have gone. So it's rather hard for me to talk about it. I'm better at handling the 'gangui' or the sail than at answering questions of that sort. But, all the same, it looks to me as if the word 'bouillabaisse' simply means 'fish bouillon'.

"I remember when I was a little apprentice, forty years ago and more, I used to hear the old fishermen talk. They didn't say *bouillabaisso*, as we do today, or *bouillabaisse* in French; they said *bouillebeisso* and *bouillepeis*. We fishermen make our meals of the throw-outs, of the fish for which there is no great demand; we put them in our pot, add water and saffron, and eat them when they are cooked with slices of bread which we have soaked in their liquor.

It is really a bread soup soaked in the fish liquor. Only, in our language, we don't say 'make soup' but 'make bouillon'. The sardine fisherman, when he shows you his pot, says: 'I'm making a bouillon of sardines'. The fisherman with a spinner will tell you: 'I'm going to make a bouillon of mackerel'. And the 'gangui' fishermen, whose throw-outs consist of several sorts of fish mixed up, simply say: 'I'm making a bouillon of fish', or, in their own speech, '*bouille de peis*'. In my opinion that's how we got first '*bouillepeisse*', then '*bouillebeise*', and finally '*bouillabaisse*'."

"We Italians," Narcisse agreed, "call it '*bouillapesce*'."

"So," Armand concluded, "it is the old soup the 'gangui' fishermen have known, made at sea in the shelter of a rock, which has become the bouillabaisse we know today. Anyhow, if you would enjoy it properly, you should catch it for yourself."

"True," said I. "One always appreciates better something one has been obliged to work for. But I congratulate you on the cleverness of your explanation. I'm sure the experts will not be able to suggest anything better."

"I don't deserve any credit for it," said Armand. "I have been a fisherman ever since I was a tiny child. I live with fishermen and I am one of themselves. I have only had to listen to them, to recall an old memory and profit by it. It's like mending a net. It isn't enough just to stop up the hole, one has to find out where it started and then follow the thread. That's the only way to make a good job of it."

So was the wisdom of the ancients expressed in a small corner of the Mediterranean, its original home, by the voice of a good sailor, descended from the Greek fishermen and the Phœnician sailors of old, heir to their experience and their knowledge.

CHAPTER V

THE TRIGGER-FISH OR BALISTES, AND THE ARMOURED FISHES

Balistes, the scientific name of this fish, makes us think of things quite apart from the fish we are now about to consider. It reminds us of the old Roman ballista, a huge catapult used in sieges, which hurled great projectiles to break down the gates of a city, or make a breach in its walls. It reminds us of the perfection and power of modern artillery, and its principal science, ballistics, whose name is in strict accordance with etymology, its origin being the Greek word *ballein* which means to hurl. So when we hear of a fish called *Balistes*, we expect to find a creature whose size or capacity is in keeping with the implications of the word. It is with a certain amount of disillusionment that we discover an animal of medium, even small size, which has nothing whatever about it resembling a catapult except the points of the dorsal fin, which can stand up sharply like arrows.

If the trigger-fish is somewhat disappointing, when we read its name underneath some dry-looking specimen in a collection, it is quite a different creature when alive. Its many species are found in every sea, tropical and temperate. One of them, *Balistes capriscus*, lives in the Mediterranean, on the Atlantic coast of the Iberian peninsula, and even so far north as the gulf of Gascony. Fishermen sometimes find it in their nets, and they call it " pig " or something of the sort, as they often do in the case of clumsy-looking, large-headed fish. We shall not have any difficulty in finding specimens to study.

It has a big, oval, flattish body, compressed at the sides and much higher than it is thick. Instead of the thin garment of scales to which we are accustomed, its whole surface is covered by a compact suit of armour, made up of lozenge-shaped plates like a mosaic. The animal is surrounded and protected by this cuirass, a delicately inlaid coat of mail, which the playing light makes to sparkle with colour. This colour, brownish in general, has gleams of blue and gold, particularly near the back, where the blue tones extend in longitudinal stripes.

The head is curious. Like the trunk, broad and flat, and armoured also, it has two round eyes and, in front, a little slit of a mouth, framed by thick lips. These lips, almost white in colour, but with borders not unlike our own, stand out from the dark cheeks like the bloodless lips of a corpse; now and again they pucker, contract at the corners in a sort of grin, or open and close, as though the creature were speaking. This almost human resemblance is accentuated when we look at the teeth, long, chisel-like, and set side by side. The fish's appearance is certainly striking, and the fishermen's stories, which always seem to border on the miraculous, have not failed to make the most of it.

The keel-shaped back has two dissimilar dorsal fins. The first, the relatively short front one, is supported by three strong, sharply pointed rays. It can either lie in a groove round its base, or set itself up quickly when the animal so desires; hence the name Balistes. The second one is behind; much larger, more supple, fixed and not capable of being shut up; its opposite number or counterpart is the anal fin beneath the belly. Both, almost triangular and blue-veined, surround the hinder portion of the trunk like two large waving sails. Right at the back, a little behind them, is the caudal fin, almost as large and flexible as themselves and shaped like a broad vertical flapper.

Though the trigger-fish are adequately furnished

with median and unpaired fins, they are certainly not so well equipped with paired fins. The pelvic fins are replaced by a pointed tubercle. The pectoral fins are small and short, but make up for their size by affording a capacity for movement not possessed by other fish. Usually, in these other fishes, the pectoral fins can move from above downward and backward, but not forwards. Their movements are consequently limited, the articulations being of restricted capacity. This is not so in the trigger-fish, which can move these fins forward. Sometimes, if we watch these creatures moving about in an aquarium, we may see the curious phenomenon of a fish bringing its pectoral fins over towards its eyes, as the higher vertebrates do their arms, and covering a part of the cheeks. This indicates a perfection of articulation of which we have another and better example in the rays of the front dorsal fin.

There are three of these rays. The first and strongest, a solid point bristling with spines from the base to the top on its front side, is succeeded at a little distance by the second, smaller, smooth, sloping like a buttress; the third, smaller still and further off, is entirely behind. All three, so far as their action is concerned, are closely connected one with another. The fin is able to close up in its groove or to erect itself; it is possible, when the animal is alive, to stretch it out without any difficulty by raising the first ray; but it is impossible to do the opposite, and fold the whole wing back again in its groove by pressing on it. A fisherman can always prove this to you. This particular dorsal ray, once extended, remains motionless, its spines projecting, quite different from anything we notice elsewhere. We might have to break the first ray before we could lower it. Firmly wedged, it resists all efforts. But we can lower the second, or the third, ray and so secure the desired end without trouble; the fin closing up completely.

The reason for this is that these rays have a ball and socket articulation like those of the limbs of the higher vertebrates and they are furnished with certain refinements which facilitate their action. They are attached to a basal bony, keel-shaped structure, lodged in the tissues of the back. The first ray is jointed to this by means of a two-lobed head and above them, on its hinder face, there is a depression turned towards the second ray. This also has an articular head with two lobes, but these, stretched out and extended like a pair of tongs, overlap the basal piece, and can slip along horizontally. Further, this head has on its front surface, turned towards the first ray, a projection which fits into the hollow with which this is furnished. Now we can understand the mechanism. When the fin is set up, the second ray slides forward and comes closer to the first, fitting its projection into the depression just as a bolt slides into its socket. It is impossible, so long as this bolt is shot, to pull down the first ray. In order to do so it is necessary to press upon the second, slide it back, and so bring out the projection from the depression, or the bolt from the socket. Then the first ray, no longer having anything to support it, may easily be brought down, bringing the whole fin with it. As for the third and last ray, a ligament connecting its base with that of the second makes it possible to act upon the latter from a distance, make it slide, and so lower the fin.

In vertebrates, the bony skeleton is a complicated piece of apparatus, made up of a number of pieces, which sometimes support one another in such a way that they hold together like parts of a framework, sometimes move one over another to allow movements of various parts of the body. In fishes, the supporting articulations are incapable of movement, or nearly so, and they are the commonest, often the only, articulations. The body is all of a piece; the movements are limited in extent. This is the very opposite of

what we usually find in land vertebrates, whose limbs, in their various parts, or in their relation to the trunk, possess, thanks to their ball and socket joints, ample capacity for movement. In this respect the two principal groups of vertebrates are obviously opposed. It is interesting to observe that this opposition is not absolute, for certain fishes, like the trigger-fish, possess in one of their fins an articulated mechanism. The trigger-fish is not the only example. The great fresh-water cat-fishes of subtropical regions, several of which are to be classed among walking fishes, have similar arrangements for their thick rays with movable points. Indeed, they are occasionally still more perfected, and they sometimes have articulations like a sort of bayonet fitting.

But all this, in spite of its interest, is only a detail. The main feature of the trigger-fish is its cuirass. In this respect it is distinguished from the majority of other fishes, which have nothing like it, and can show as a covering for their bodies nothing more than a thin flexible garment of scales. But the trigger-fish has rivals. The sea-horse is one, and its cousin, the pipe-fish. The gurnard, a walking fish, is another; its species have protection for their heads in the form of a solid cap which often extends to the neighbouring parts of the trunk. Another fish of the same family, however, surpasses it; its cuirass, still thicker and more complete, bristles with a number of spines which project as if to increase their defensive value. This is the armed or mailed gurnard.

This species, well named, for its French name, "Malarmat," taken from an old Romance dialect, means "heavily" or "evilly" armed, bears a close relationship to the true gurnard. The little finger-like tentacles formed by the free rays of its pectoral fin are only two in number, unlike the true gurnard, which has three. Like the latter, it lives in muddy flats near the shore, in fairly deep

water, even extending into the grass-wrack fields. Fishermen know it well, for it is fairly common, if not of much use for food, especially in the warmer parts of the Western European seas. In the Mediterranean, and off the coasts of Morocco, Portugal and Spain, it is frequently met with, but, in the Gulf of Gascony, it is scarcer, and further north is only occasionally caught.

In this fish, which has greater protection, the armour is complete; it surrounds the whole body from head to tail, leaving only the fins free. The head is confined in a helmet of one piece, large, hard, and bristling

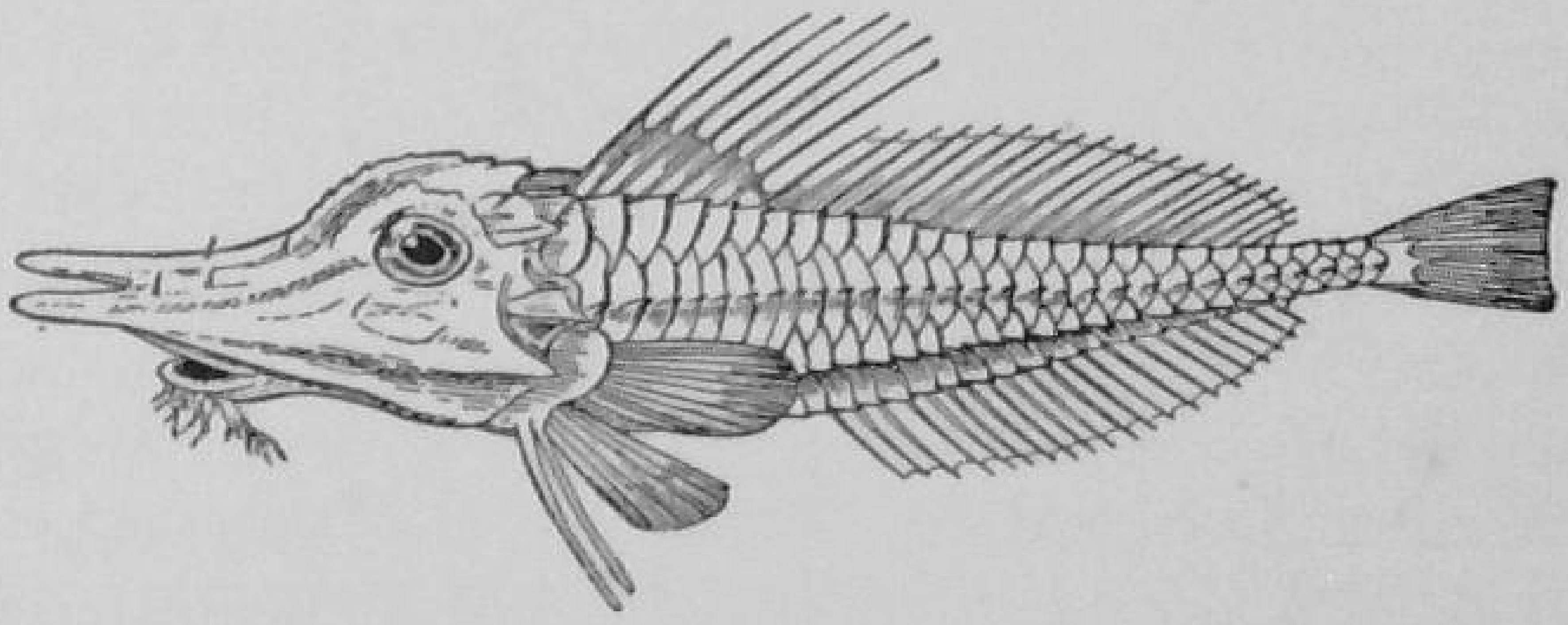

FIG. 14.—Mailed Gurnard. The fish may reach over a foot in length.

with spines, having two great flat horns in front like those once worn upon a warrior's helmet. The question has been asked: Does the creature use these horns as spades for burrowing into the mud and digging out any prey that may be hidden there? Observations in the aquarium seem to show that it does not. The helmeted head, which looks so alarming, has under it a toothless mouth, the position and shape of which enable it to browse upon the bottom, and pick up there without any need for digging, the little animals, crabs, and shell-fish, which ordinarily live there.

Then, besides the helmet, the trunk, from the shoulders as far as the caudal fin, is covered by a suit of armour composed of eight pieces, these pieces being

broad plates of bone firmly jointed. Under the belly, the plates are larger and thicker than those on the sides and back, and form a shield which gives the final touch to the whole outfit. The bones, all along the body, have projecting spines. There is an extraordinary resemblance to the old Japanese armour which was made of carved and interlocked pieces. This, however, hardly compares as regards finish with the natural armour which surrounds the mailed gurnard. As a protection it could hardly be beaten: everything is perfect, the strength of the cuirass, and the bristling array of spines or spurs.

Yet, in spite of all this elaborate protective armament, the creature retains to a very large extent the mode of life customary in the majority of fishes. Near it we find other species which have no armour at all and do not seem to miss it. The armour, although it definitely serves as a protection, is not an obtrusive factor in the creature's existence; its appearance is more impressive than the use made of it. Moreover, this same appearance prevents us from taking it too seriously. We note a contrast in this respect between the trigger-fish and the mailed gurnard. The former, dark coloured, with spurs upon its dorsal fin, really looks like a warrior in full array, with his daggers ready for action either in attack or defence. The mailed gurnard, on the other hand, with its delicate shades of colour, red on the back, paler red on the sides, and faint pink on the belly, seems to belong to another and gentler type, strictly defensive, and concealing its defensive weapons by bright coloration.

We often credit Nature with motives like our own, which originate in our own minds, and these, by a process of projection, we proceed to attribute to her. To assure our own safety we need arms and protections and, when we discover in certain animals the presence of weapons like those to which we are accustomed, we conclude that they are in the same

category: the words armour, helmet, sword, which we use because of the obvious resemblance, seem to make us assume an identical rôle in both cases. But when we do this, we disregard natural conditions; life, in its processes, has no need of such an arsenal of weapons. It is true that there is sometimes a protective covering, and that sometimes too we find the capacity to attack and pierce and bite. But the actual purpose here is subordinate to the necessity of having in or around the body a skeleton, an apparatus made up of hard pieces able to support the soft parts and prevent them from collapsing. This is the necessity upon which the others depend. The main need is to support the organism, to keep it in a state of equilibrium and allow its cavities room for expansion, to provide opportunity to fulfil its functions. The rest comes afterwards, as an entirely secondary consideration, only if circumstances permit of this further utilization.

The presence of a supporting apparatus, a skeleton, is a most frequent occurrence, so frequent that we tend to take it for granted. Animals completely devoid of it are comparatively rare. Sometimes the structure simply surrounds the body; sometimes it is embedded in its substance; sometimes both one and the other. The skeleton may be external or internal, or in two parts, one internal and one external. The important fact is that it exists, that it does serve to support the soft tissues, and, if necessary, reinforce the muscles. Its function is general, and it is observed in the simplest of creatures.

Its presence is a mark of the essential, characteristic quality of living matter, that of creating and building up symmetrically. Life is of itself an association of energies which manipulate the particles of matter and, at various stages, give them forms, which ultimately take shape as organs and individuals. Every creature has a metabolism of its own, a quality of assimilation

and structure-building peculiar to itself. The production of a skeleton is evidence of this process. The apparatus, since it has the function of supporting, must have a compactness, a power of resistance, which can be dispensed with by other organs. The ordinary tissues seldom have sufficient firmness, and therefore a process of mineralisation is applied to its formation, which consists of adding to itself mineral substances which will ultimately render it more solid. These it draws from its environment, taking them with the materials of its general nutriment. It keeps them within itself instead of rejecting them, and adds them as a reinforcement to itself.

To its separate parts, thus constituted, the skeleton gives a form in keeping with the symmetry of the organism. Although the substances at its disposal for this purpose are not many (they are confined to silica and certain salts found normally in solution in the waters of the globe), the creature utilizes them and attains the necessary end. Usually the amount of this natural solution is very small, a litre of sea-water containing only one and a half centigrams of dissolved silica, and one and a half grams of lime salts, while most fresh water has even less. But still the process of vital assimilation collects these mineral products as they are taken in with food, keeps them, distributes them to the required point, and finally establishes their ultimate condition.

Even many of the unicellular beings, in spite of their usually microscopical size and the simplicity of their structure, have a skeleton. In it we find a kind of opposition, even of exclusion, between silica and lime. The mineralizing substance is either one or the other, it is never both at once. It looks as though, in creatures quite closely related, assimilation took two different, divergent directions, having as their only point of resemblance the main purpose behind them; one concerning itself with the fixation

of silica, the other with that of calcareous salts. This quality of building up a skeleton from mineral substances, which we find even in the lowest animals, is continued in others, and finally ends in the predominance of the calcareous salts.

The minute plankton, among its myriads of tiny living creatures, contains many which possess a skeleton. This is often of such extreme complexity that it is not rivalled even among the highest animals. In the surface waters of all the seas upon the globe are found vast numbers of organisms which compose one class, that of the Ray-animalcules, the largest of which are hardly bigger than the smallest pin's head. Almost all have a siliceous skeleton, the many parts of which are either jointed like armour or else spread out in a series of rods running into the interior of the creature. It is impossible to convey any impression of the delicacy and extraordinary diversity of these tiny rods and the fine plates, whose regular, geometrical construction effects miracles of architecture in these tiny creatures. The finest tracery of a gothic window, the most elaborate pieces of carved ivory from the Far East, are completely outdistanced by these gems of construction brought about simply and solely by the vital activity of an organism which, in every other respect, is so insignificant. The little creature has a very important lesson to teach. It shows us that Nature, not taking into account the stature of her creatures, dispenses her riches to all who owe their existence to her.

Beginning with these minute beings, and ascending the scale of animal life, we find at every stage different types of supporting apparatus. In the bodies of the sponges there are, according to the species, calcareous rods or siliceous spikelets of many forms, or those elastic filaments which give our household sponges the properties we value. The sea anemones have soft bodies, but their nearest neighbours, the corals, are

surrounded by a thick calcareous skeleton which acts both as a support and as an envelope. Beside the worms with naked teguments we find others which shelter themselves in a mucous or calcareous tube which they have themselves produced. The vast Mollusc group is characterized by the frequent possession of a calcareous shell, either single or divided into two valves; in this class creatures without any protection or supporting structure are in the minority. Then there is the still more extensive group of articulated animals, including the Crustacea and Insects, which have an external skeleton, sometimes confined to a sheath of chitin, a horny organic substance produced by the skin, sometimes thickened into a carapace, an external cuirass, the chitin of which is strengthened by lime. So we come to fish and other vertebrates, and see that the possession of surface armour, and internal skeletal constructions, is not a new or special attribute at all, but only the sign of a general condition.

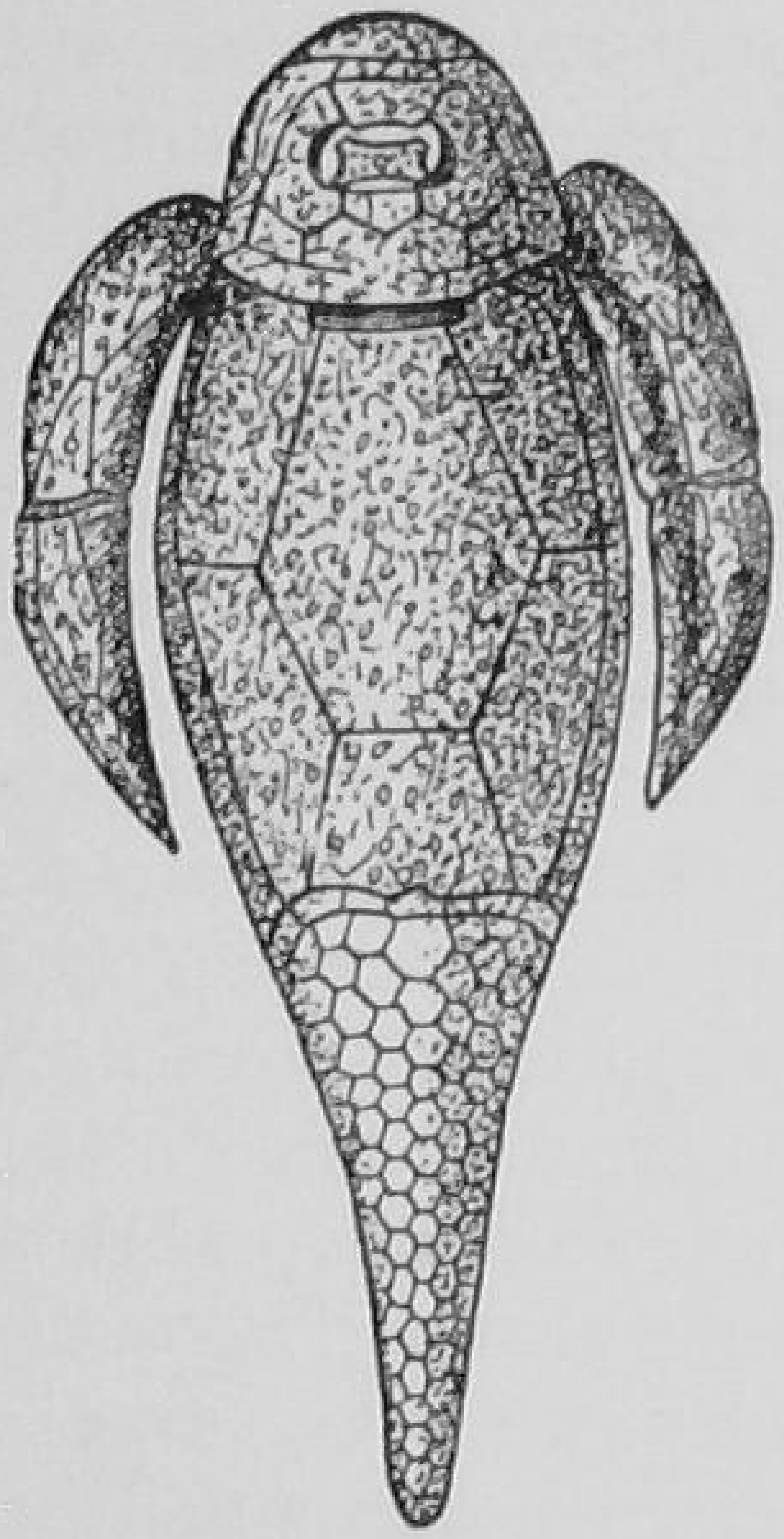

FIG. 15.—Fossil armoured fish (*Asterolepis cornutus*) found in Devonian strata of the Palæozoic era.

The trigger-fish and the mailed gurnard are not the only armoured fish in Nature today. There are others, some of which we have already mentioned, such as the sea-horse with its grasping tail, the coffer-fish with its clumsy body, the bichir and bony pike which live in the fresh waters of Africa and America respectively. In the last of these, the cuirass extends all round the body and is made up of plates, the main substance of which is bony. This protects the inside

of the organism and also serves to support it. It is a part of the external skeleton, forming an outer and superficial layer which completes and consolidates the deep inner skeleton which is not so strong, since it is mainly made up of cartilaginous tissue. This is an interesting dual construction which reminds us today of forms which were more frequent in ages past. This peculiarity is not now so marked in most vertebrates, for their internal skeleton is mainly composed of bone; but it is still to be remarked in the development of the embryo.

This appearance and development of the skeleton of vertebrates in the embryo is very remarkable, especially in the case of reptiles, birds, and mammals. At first the parts of the skeleton, when they begin to take shape, are not bone; many are cartilaginous. Then, as they develop, they change and become gradually more and more bony. The strong bony tissue, impregnated with lime, is gradually substituted for the softer tissue which preceded it. The child at birth has a soft and mainly cartilaginous skeleton which hardens with growth and gradually ossifies, being enriched by additional plates, like the bones of the dome of the skull, which are not osseous to begin with but membranous. In the species of fish related to the bichir and bony pike, we find corresponding plates; they form a superficial covering, a kind of outer skull, which is not even covered by the skin. If we consider all these facts together, it looks as though the ossification of the skeleton, a notable advance, since it gives the supporting apparatus its main quality, that of strength, proceeds partly from the outside of the body to the inside, as if it were concerned to bring inside, and there make use of, pieces originally shaped outside. This brings us back to a very old story, that of the armoured fishes of other days.

At the present day, the principal species of fish,

those which have been commonest since the end of the Mesozoic era, have an ossified skeleton inside, and a covering of thin flexible scales outside. The armoured species are in a minority. During the later Palæozoic era this was not the case. The fossilized traces of the fishes of these days consist especially of armour, which alone made up the principal part of the supporting structure. Unlike what we find in the fish of today, this structure, instead of being mainly within, was mainly external. A strong, firm cuirass stiffened the body, surrounding it like a suit of armour, and this made up the essential part of the skeleton. The remainder, which was cartilaginous, has not come down to us.

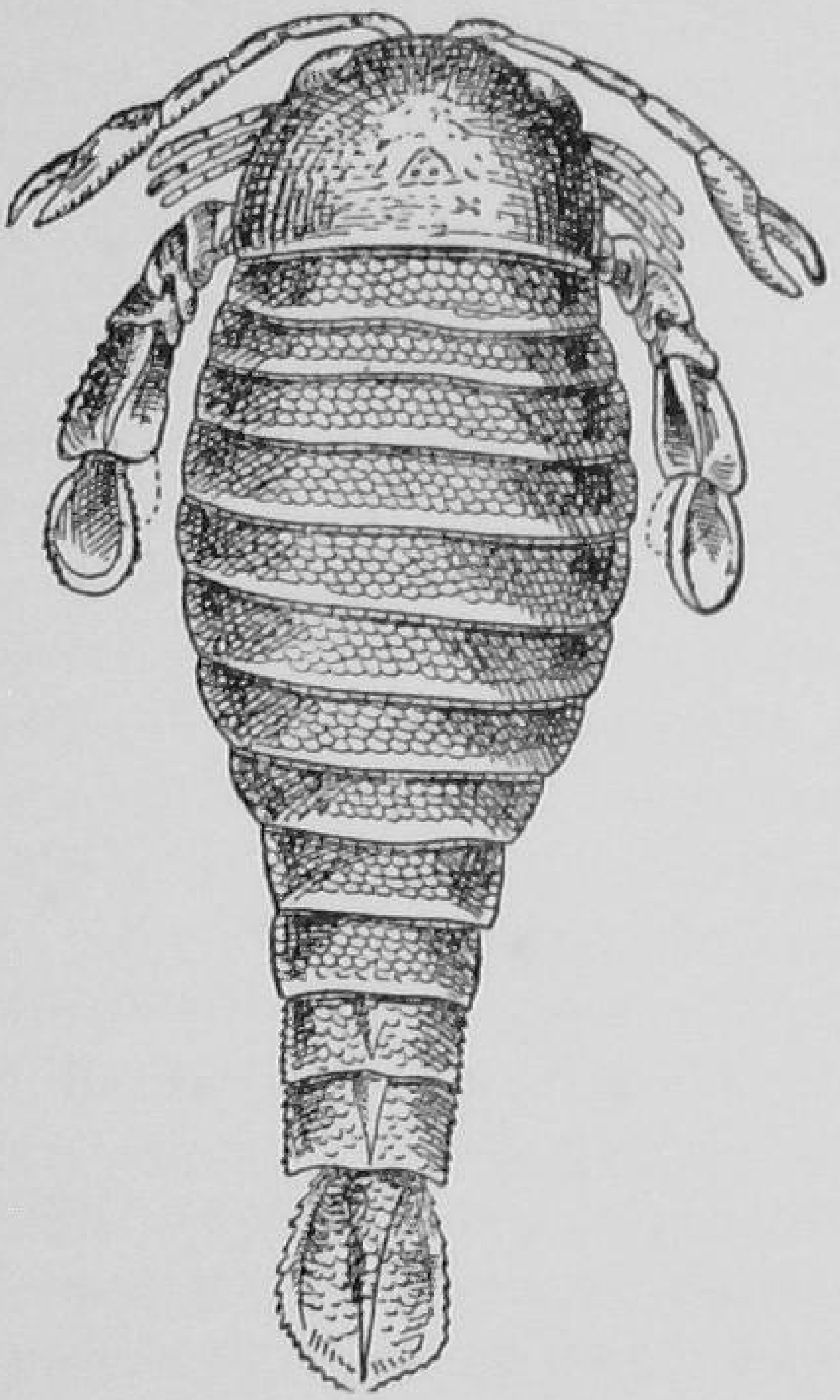

FIG. 16.—Gill-breathing Sea Scorpion (*Pterygotus anglicus*), a fossil found in Devonian strata of the Palæozoic era. Some members of this group might be as much as six feet long.

These armoured fishes of the past displayed a diversity and originality of structure which we do not find in those of this age. Some of them were very large, more than six feet long. One of the best known of them, *Pteraspis*, had the front part of its body held in a strong shield, made in one piece. Another, *Pterichthys*, whose armour was made up of broad, welded plates, had pectoral appendages resembling limbs spreading like powerful oars at the side. These species occupied

the seas in great numbers. When we see their remains, we cannot help thinking of the soldiers of the Middle Ages, all in coats of mail and helmeted, encased in defensive armour. So, in seas that have now disappeared, most of the fish were similarly covered with plates and shields. But they were not the only fish in the sea. Beside their fossils, we find isolated sharks' teeth, the presence of which is an indication of the purpose of the protective armour. But that is all. Apart from these two groups there is no trace of any other ancient fish population of those early times.

In company with these fishes dwelt other strange creatures which looked very much like them, so much like them, in fact, that it has been suggested that real affinity existed between them. These were at one time thought to be Crustacea, being provided like them with articulated feet, and a thick jointed carapace investing the body. This group is called the "Gigantostraca". Their only living representatives are the King Crabs found in warm seas. Its representatives in long-bygone days were the gill-breathing sea scorpions known as *Eurypterus* and *Pterygotus*, with larger, somewhat fish-shaped bodies, and in some of them a pair of limbs was lengthened and spread out rather like pectoral fins. Beside them were hosts of creatures of related structure, but smaller, the famous Trilobites, which seem to have swarmed like the crabs in our own seas, looking like great wood-lice with backs divided into three lobes by two parallel furrows. Doubtless, animals like worms with soft unprotected bodies lived near these creatures which were well provided for on the defensive side, and the diversity we notice today was equally to be seen in their time. But, taking into consideration the number and complexity of the traces they have left behind, traces which we find as fossils, these heavily armoured creatures were proportionately more common

than they are today. They were predominant among the fauna.

The appearance of these vanished seas, of the population which filled their waters and crawled over their beds, the *facies* in a word, was very different from that which came afterwards, down to our own

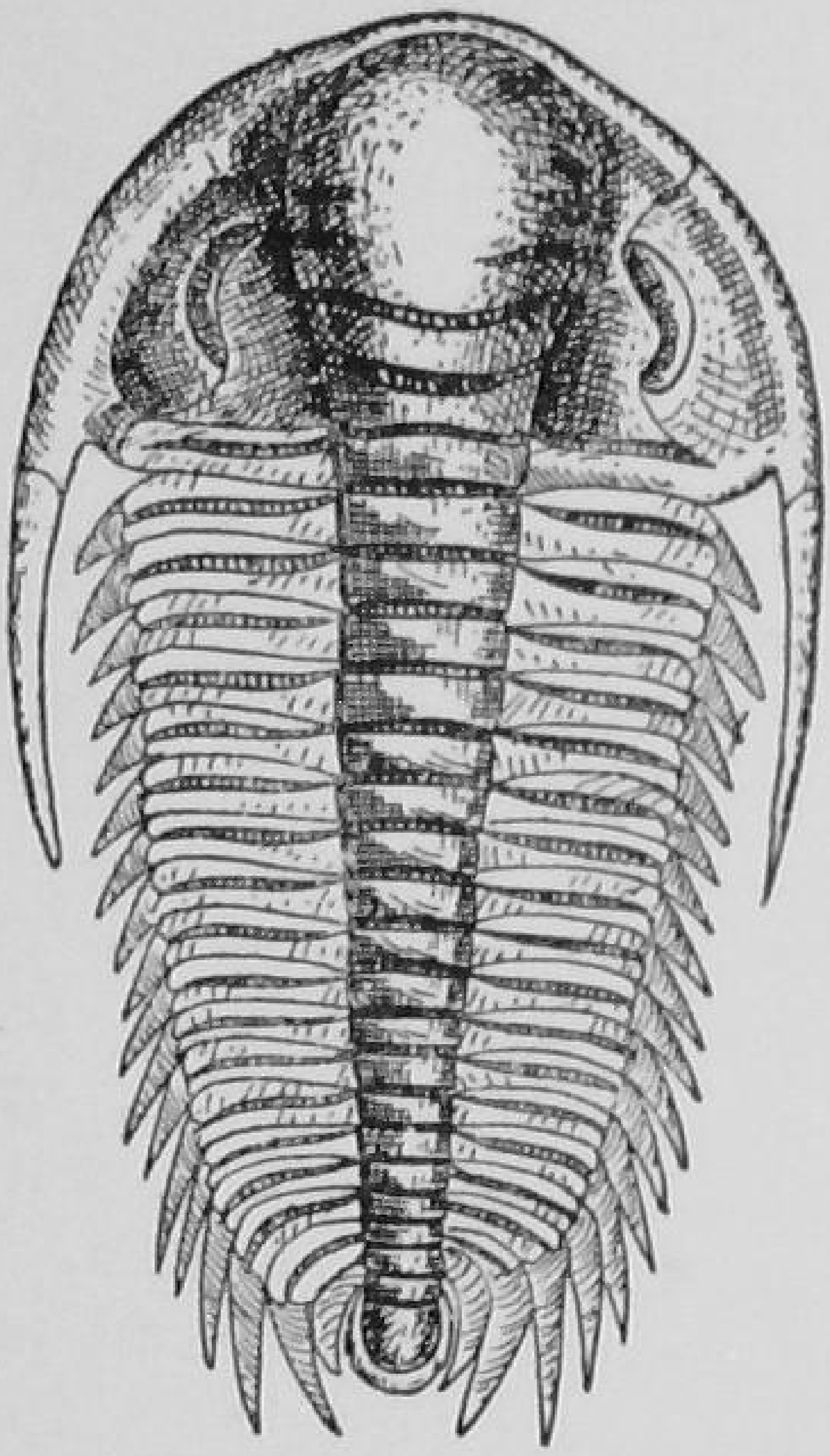

FIG. 17.—Trilobite (*Paradoxides spinosus*), a fossil found in Cambrian strata of the beginning of the Palæozoic era.

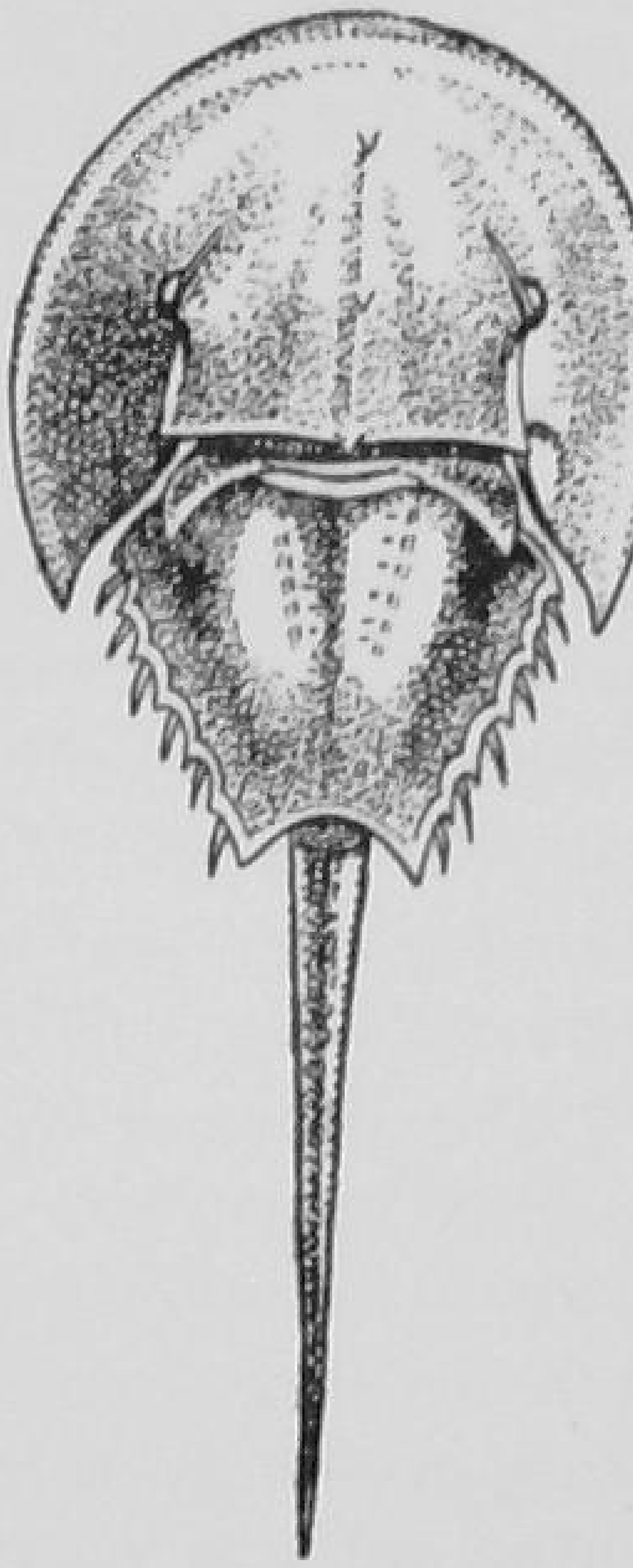

FIG. 18.—The King-crab. The body, not including the tail-like appendage, may reach a foot in length.

time. The mass of the population, so far as fishes were concerned, was made up of these armoured species, covered by an outer skeleton, and having only a small cartilaginous inner skeleton. In the Palæozoic era that population was characteristic of the oceans. In those days the continents were probably low, and of no great extent; animal life on land was meagre and restricted ; life centred particularly in the seas, and the armoured fishes were dominant

there. Their presence and multiplicity are typical of the period. The Palæozoic era belonged to them, as the Mesozoic era belonged to the reptiles, and as the Tertiary of today belongs to the mammals and birds. Except for the sharks, they have disappeared and the sceptre of the power of life has passed to others.

This first change, this transfer of power, took place during the Mesozoic era. We can follow the phases of its transformation in fossils and in the succession of deposits in which it is recorded. First the older type of armoured fish grows smaller in numbers: then we find, appearing and multiplying, fishes with a bony skeleton of the new type, more agile, more flexible, and more varied. At the same time, by a remarkable coincidence, life on land changed in an exactly similar manner. Flowering plants took the place of the heavy vegetation of flowerless plants and cone-bearing trees. Then came the insect that develops from a grub, including the many-hued host of butterflies. The huge reptiles were replaced by the smaller birds, created, as Buffon wrote, "by Nature in a moment of gaiety". Life on earth and life in the waters changed at one and the same time.

In this transformation, Nature became more gracious, showed herself more gentle to the creatures she had brought into being. She began with clumsy structures in which matter predominated; she ended by producing organisms in which the activities of life can be manifested with the employment of less material substance. On the long road of Time, which the living world has travelled since its remote beginning, difficulties grow less, and hardships diminish. As life makes progress, it grows easier. This, in fact, is the mark of its progress.

CHAPTER VI

SCALES, MIRRORS, LEATHERS

THE three words which I have placed at the head of this chapter look as though they might have been taken from some cabalistic formula, or have formed part of a sign painted outside a shop dealing in all sorts of junk; but no, I have simply taken them from a letter sent to me by a friend who owns some ponds not far from Argenton sur Creuse in which he breeds carp in considerable numbers. He used these three words to describe, as briefly as he could, the three main types of fish in which he is interested.

"You may remember," he wrote, "the experiments which several of my neighbours have just carried out at your suggestion to see whether 'mirror' carp and 'leather' carp can be raised in the places where the old breeds of 'scale' carp have hitherto been bred. Most of these experiments have turned out conclusively. The 'mirrors' and the 'leathers' have shown that they develop more quickly and more fully, perhaps even that they are more hardy. They have given a greater yield per acre. I thought I would try a similar experiment myself. In the spring, I put equal quantities of good two-year-old fish of all three types into my large hundred-acre pond. I took every conceivable pains to get the pond suitably prepared so that I could secure the best possible return. Last October I had it emptied, left it dry for three months, then harrowed it, limed it, and even manured it in places. I did not let the water back until February, and it was the beginning of March when I put in the young fish which I had kept in a tank.

"I stocked it at the rate of about forty-eight head per acre; sixteen 'scales', sixteen 'mirrors', and sixteen 'leathers'. Altogether, I put in sixteen hundred fish of each kind. Everything went perfectly, and I had no losses. I was delighted to find that everything went well during the hot weather; the pond was full all the season through, and I was not too much bothered by weeds and water plants. Now winter is nearly here and I am going to start fishing. The sluice was opened the day before yesterday; the water will be all out in about a week, and we shall be able to test the results of the experiment. I say 'we' because I expect you. I hope to have the double satisfaction of your company for a few days, and of being able to discuss with you the various conclusions we arrive at upon a subject which I consider of very great importance."

It is not difficult to understand the technical terms my friend used in his letter. The three words, "scales", "mirrors", "leathers", are used to describe three different kinds of carp, according to their appearance. There are those which have scales of the ordinary kind; those which have on their bodies broad shining scales like mirrors; and, finally, those which have no scales, but a leather-like skin. My friend spoke of two-year-old fish, showing that the fry he used had been already big and strong. They had spent two years in the small ponds in which they were hatched before they were caught and taken to the large pond in which they had just spent their third year. As a matter of fact, my friend spoke of summers instead of years, because the fish only develop during the summer and do not grow at all during the winter.

I accepted the invitation and set out on the appointed day. Before I arrived at my destination I had to cross almost the whole of the Brenne plain. The approach of winter had stripped the trees of their leaves, and I could see for miles. A vast plain, with poor, pebbly

soil through which water can pass only with difficulty, and here and there little stumpy hillocks. Shining in the sun, some close to me and some a long way off, were ponds like the one to which I was going. The countryside is full of them, and nearly all are artificial. They were made by men in the Middle Ages, by cutting dams across the depressions natural to the land, thus forcing the rain waters to collect, and turning the depressions into ponds. And these ponds were made simply to breed carp. Ever since, they have formed what might be called "water estates" given over entirely to breeding carp, and perfectly fitted for that purpose. In other provinces of France and elsewhere in Central Europe there are ponds of the same sort, constructed in the same way and for the same purpose.

When I arrived, everything was ready for the operations which were due to begin next morning at a very early hour. At the deepest point of the dams, there is a large opening which can be opened or closed at will by a sluice or something of the sort. When this is closed, both water and fish are confined in the pond. When it is opened, the water flows out, and it is only necessary to put a net or a wicker network across the opening to hold back the carp and prevent them from escaping with the water. In front of and below the sluice, at the bottom of the pond itself, is a large hollow prepared beforehand lower than the actual pond level, and in this a certain amount of water is kept back. In this kind of ditch the carp collect and, since it is not deep, the fishermen can get to work without any particular difficulty. It only remains to take out the carp. The breeder must take care that the water flows out slowly, so that the fish are not frightened but go down gradually in the direction of the sluice as the level falls. A week or two is often devoted to this operation and, when it is properly done, when it is carried out gently and smoothly, none of the

fish are left on the bottom of the pond. By degrees, all the carp go down to the fishing point where they can easily be secured.

I love to see the operations which are carried out in fishing of this sort, the keenness—one might almost say the exaltation—shown by those who take part, in spite of all the disagreeable conditions, the chilly temperature, sometimes rain or mist, of a winter's day. From the owner to the least of his hired men, all are wildly enthusiastic and interested. At last the pond will be made to give up its secrets. For eight or ten months, sometimes more, since the moment when the young fish were put into the pond to grow, they have remained in that pond unseen; there was no means of finding out what was going on. Were they prospering, or were they decreasing in numbers? There was no sign by which this could be known. Was their development proceeding along regular lines? Were the otters, the birds that frequent the marshes, all the beasts of prey which feed upon fishes, doing their deadly work? Finally, was the harvest, a harvest similar to that which the farmer sees coming in his forcing grounds and fields, but which the fish breeder cannot follow because it is prepared in the bosom of the water, was that harvest going to be as good as was hoped for? Only when the fish were taken could this be known, and that is why all the incidents of the reaping were followed with such keen interest.

On this particular morning, the temperature at daybreak was icy. It had been freezing during the night. A light mist lay over the distance in the direction of the forests, but it was clear enough close by. My friend and I rose early and were at the sluice before dawn. Behind us was the dike, like a wall fifteen feet high or so, faced with stone, covered with mud, joining the banks of the pond on either side. A few days before, the water still covered it; little waves raised by the breeze beat gently against it.

Now the water was gone and its stone mass stood out dry like a rampart. Before us spread the muddy bottom of the pond like a grey, yellow-spotted plain, undulating in the direction of the general lie of the land. It too was now dry, which once was covered by the mass of waters in which the fish had lived. Here and there were mounds on which were tufts of drooping reeds. At our feet was the fishing point, the only place where there was any water left. The carp were collected there, inert, made stupid by the cold. We could see them in a confused mass, like large pebbles.

But, in the cool of the morning, in the pale red light of a wintry dawn, a certain liveliness began to manifest itself. When one of these large ponds is fished, it provides the occasion for a sort of local fête with all its regular attendants. Neighbours ready to lend a hand began to arrive upon the scene, women and children with baskets to hold the fish which was generously distributed to those who came to watch and help, carts to take off the harvest, and interested spectators whose numbers kept on increasing. Near us, at the foot of the bank, just at the edge of the fishing point, workmen were getting everything ready. Some spread straw and old nets on which to put the carp when they were taken out of the water; others arranged materials, tools, basins, tables, weighing-machines and baskets, ready for washing, weighing, checking, packing the fish; still others were lighting great fires of wood in the open so that anybody who felt cold or damp could warm and fortify himself against the elements.

When all the preparations had been completed, the fishing began. A group of men, carrying a long net, spread it over the far end of the fishing point, then brought it along towards the sluice, driving the carp before it. So they collected the fish into a narrow space where it was easier to capture them. Then one man, with great boots covering his legs and thighs,

went into this water crowded with fish, and busied himself catching them with an implement like a shrimping net. He plunged it into the water, drew it horizontally for a moment and, each time, brought out several fish. The carp, stupefied by the cold, made no attempt to escape. They allowed themselves to be captured and lifted out, like inert bodies. Then the fisherman set them down on the nearest straw beds and went back to the water for another haul which he carried back in the same way, going and coming all the time.

While this was going on, his comrades on the bank were busying themselves about the fish already brought out. The carp, although the cold had certainly affected them, yawned, raised and lowered their gill-covers in the effort to breathe, flapped their tails, and occasionally turned a somersault. They were taken one after another, passed through a washing tank to clean the mud off them; then weighed, counted, and put into baskets to await the final packing. Everyone went about his work, chatting, laughing, singing, sometimes going off to warm at the fire hands almost frozen by the chilly water, then returning to his appointed place. Everyone was on the *qui vive*, workers and curious alike, both those who had a job to do and those who were only there to look on. And every moment there was something to attract and hold the attention, a summons to come and see a specially fine specimen, or a call for assistance when there was a moment's difficulty. And so passed hour after hour and everybody was content and interested.

Yet the hours did pass, and the morning drew near its close. It was a fine day and, the sun mounting higher and higher in the sky, its warmth and light, although not very strong in the winter season, produced their unfailing effect. Voices grew louder. Less frequently was the fire visited for warmth. The busy hands grew busier. Even the business of fishing

became more absorbing. The last of the carp, roused from their comatose state, made more efforts to escape; they avoided the net, and several attempts were necessary before they could be secured. Finally, by making more use of the large net sheet which hemmed them in, further restricting the confining space, they were captured more readily, since there was less room for them to move in.

These last captures were most exciting because of the efforts of the fish to escape. The carp made off as soon as any attempt was made to get near them; they darted in all directions, slipping between the booted legs of the man whose work it was to seize them. Since there was no great depth of water in the small space left to them, their backs came above the surface, projecting out of the little waves made by their attempts to escape. But at last, one after another, they were all captured, and the moment came when nothing was left of the multitude there had been earlier in the morning.

Meanwhile, the last stage was reached in the handling of them, the business of getting them away. The fish, washed, weighed, counted, still alive in consequence of the care devoted to covering them with damp cloths, were placed in willow baskets, or hampers, and set aside at the foot of the bank. There, they were lifted up to the top of the dike, brought to the waiting carts, and put in them. These carts, covered with waterproof sheets, served as tanks in which a certain amount of water was put, and here, ultimately, the catch was placed. As soon as the loading up was done, the carts set off smartly for the nearest railway station, where the final stage was completed, that of putting the carp into a waggon tank which, a few hours later, would carry them, still alive, to the markets and the consumer. And that was the end. The whole mass of fish, produced and grown in the millions of cubic feet of water which the pond with its hundred-

acre surface and six to ten feet of depth contained, was now collected in tanks of a few tons, in which they would journey to their destination.

I sat down beside the baskets containing the carp and, taking some of the fish in my hands, began comparing them with due attention. As the three kinds were separated, they were put into baskets containing one kind only. Around me were "scales", "mirrors", and "leathers", and it was a simple matter for me to examine them in detail, see in what respects they resembled one another, and note their points of difference. The "scale" carp belonged to the old type common to the locality, which had long been raised in most of the ponds in that part of the country, but the "mirror" and "leather" carp had a different origin, for they had been brought from Central Europe only a few years before.

In structure, the first-named displayed a remarkable degree of uniformity. Their scaly coat covered the whole body, leaving no bare spot anywhere; it provided the creature with a light covering which, though tough, was sufficiently supple to yield at every turn. These overlapping scales, set one upon another like the tiles of a roof, were perfectly regular in arrangement in all the specimens. Each has a large part of its surface covered by the one above it, and the visible part of it, covering the corresponding part of the one below, is four-sided with curved edges. Each fish has the same number, or practically the same number, of them. Their equality, their fitting together, bring them into regular longitudinal lines and slightly oblique transverse rows. Each fish has about forty of them in a longitudinal line, and a dozen ranging from top to bottom of each side. This figure is fixed and never varies; it is settled when the fish is quite young and never alters. The scales are tiny to begin with, but grow larger with the development of the body, always keeping their place, number, and relation.

I take off one of these scales and see how it is made. It is a thin, hard plate, elastic because it is so thin, and broader than it seems from outside because most of it is hidden beneath the one in front of it. I have to make a decided effort to get it loose, and I discover in those carp whose skin is still intact, that it is not really entirely on the surface, but fixed in the substance of the skin and, as it were, contained in it. The soft tissues which hold it, although they are both fragile and tenuous, serve to produce it and make it grow. As the surface of the body gradually becomes enlarged, these containing capsules grow, and with them the scales which they contain. This growth comes about by the formation of new substance around that which already exists. Consequently, when I lift up the scale and look through it, I can see within it a series of fine concentric lines which correspond to zones set down one after the other.

When the growth stops, which is the case during winter, the scales cease to grow, but they begin to grow again the following spring, when the general process of development is continued. But, as the interruption has occupied a fairly considerable time, the new substance does not usually completely resemble the old, and when we look through the scale, it is obvious that there has been a temporary cessation. Thus we may discover the age of the carp, the interruptions taking place only once a year, in winter, and similarly, the periods of growth being confined to summer. In the particular scale at which I am now looking I perceive the traces of two stoppages, alternating with three periods of growth, and this shows me that the fish, which has had three consecutive stages of growth, has lived for three summers and two winters. Three summers, then, represent its epidosic age, its age of growth, from the Greek word *epidosis* which has the same meaning, whereas its chronological age actually amounts to only two and a half years.

Every now and again, the carp in the basket before me show signs of movement and jump up. The light, playing on their bodies, enhances the bronze and golden flashes which accentuate the beauty of the scales and are produced by those scales. These flashes of light are given out by the scales themselves, which are, in fact, thin, transparent blades, which let the light pass through them, breaking it up in the process. The iridescent flashes, resulting from this physical action, enhance the underlying brownish hue of the skin due to the chromatophores (or cells with a coloured pigment) which are included in the substance of the capsules by which the scales are surrounded.

But when I turn to the baskets which are filled with " mirror " carp I find quite a different state of affairs. Here the reflections are more intense, more varied, and even more beautiful, but they are also more localized. There is hardly any sign of the delicate coat of scales patterned somewhat like a draught-board and looking like carved marquetry. Instead, over a dark brown skin we find broad glittering scales, much larger than those of other carp, and set out in three longitudinal rows on each side; one in the middle of the side, one near the belly and one near the back. These three bands, sometimes supplemented by isolated scales scattered about the body, stand out upon the dull background of the rest of the body which has no scales at all. In them we observe extremely diverse plays of light and iridescence like that of the thin plates. These scales—which by their brilliance really deserve their nickname " mirror "—give out all the reflections to be seen in polished metal. Sometimes displaying every flashing glorious hue from gold to silver or steel; sometimes becoming dull, then bursting forth again like sparks, they give the creature a strange, surprising appearance of its own.

The baskets of " leather " carp are quite different from all the rest. In them is no play of light, no

sparkling reflection. We find in them only dark shades, lightened here and there by brighter patches at the fins, or at the lips when the mouth opens. The name of these fishes obviously comes from their skin, which is entirely bare. It is a covering like supple leather, thick, compact, and brownish in colour. There are still a few scales to be seen, differing in number in different fishes but irregular in shape and quite unlike in appearance, sometimes included in the substance of the skin, sometimes projecting and easy to see, but always situated at the base of the fins. Everywhere else there is only the skin to serve as a protective covering.

While I was making my examination, basket after basket of fish passed me on its way from the fishing point to the carts. At last they all disappeared and the job was done. My friend, who had been superintending the operations from first to last, came and sat down beside me, with a note-book in his hand in which he had put down the items, as the numbering and weighing were carried on. He hurriedly added up a few figures, then cried:

"Oh, well! That's good enough for me. Indeed, it's a better return than I expected. I put in four thousand eight hundred young fish, and we've just taken four thousand six hundred and fifty-three, weighing altogether more than eleven thousand pounds, nearly two and a quarter pounds a fish. I know my pond is a good one, and fish get on well in it. It was a good summer and I did all I could to make sure that nothing went wrong. But all the same I didn't hope for a result like this. It's far better than the average for previous years."

"What is the proportion between the three kinds?" I asked him. "I noticed that you were at great pains to count them separately. I've been sitting near the baskets all the time and I made sure that they didn't get mixed up. So the figures you've got there are reliable enough."

"The improvement is in the 'mirrors' and 'leathers'", my friend answered. "They all reach a couple of pounds, and many of them more. Some, I see, weighed getting on for three pounds. The 'scales' on the other hand are not so good. Most of them don't amount to more than a pound and a half or a pound and three-quarters. And, as their heads are larger in proportion, and there is more bone in them, their flesh is not so much as that of the others. It's really quite remarkable. I know what I shall do in future. I shall specialize in the 'mirrors' and 'leathers', and not bother about the 'scales' we usually stock in this part of the world. For the time being, at any rate, until I succeed in breeding the best possible type. And I expect to get to work before long."

My friend was silent for a while as he looked quickly over the pages of his note-book. "It is funny," he said at last, "what a difference there is between these local carp, with their regular dress of scales, and the others, 'mirrors' or 'leathers', which have their skin either partially or totally bare. Yet they have all lived side by side in the same pond, have eaten the same food, and shared the same living conditions. Yet, as we see, the others have gained much more than our local fish. That must be a very tempting problem for you, a naturalist."

"Yes," I said, "it is an interesting problem, and deserves to be investigated. You know, as well as I do, that the 'leather' and 'mirror' carp have always been what they are now, or at least from a very early age—in the case of the great majority, at any rate. They do not begin by having normal scales which gradually become modified as they increase in growth. Their peculiar condition is original, appropriate to their particular organization. It arises spontaneously almost everywhere. In the old ponds, both natural and artificial, where the common scaly carp are left to their own devices, we find in greater or fewer numbers,

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but always exceptionally, certain specimens affected by this difference in the scaly structure which makes them 'mirrors' or 'leathers'. Breeders, who noticed that these particular specimens were usually larger than the others, decided to pick them out. So it was that these privileged kinds were secured, these kinds which grow rapidly. And, as you know too, the characteristic disappears as it came. If there is any break in the constant selection of qualified reproducers, in a few generations the carp return to their original dress of scales, and the meagre size which goes with it."

"I know," he said. "I remember how, during the last century, certain precocious types were created by such a process of selection. But what I don't know, and what I am asking you, is how there can be any relation between the change in the scales and the rapidity of growth. Please note," he added, "I don't ask you *why* this connection exists; I shall be quite content if you will tell me *how*."

"Even if we keep the question within such limits," I replied, "it is fairly searching. It is much more complex than it seems on the surface, and we do not know all the facts that we shall have to know before it can be answered. It may be that several causes come into play, and not one only. The processes of life are so many and so intricate, causes and effects at one and the same time, that we cannot be perfectly certain about them. As a matter of fact, this change that takes place in the scaly covering is the consequence of a diminution in the assimilation of the mineral salts which go to build up the skeleton; it is a corollary of the presence of shorter and softer bones. Here we are reminded of what happens in the cartilaginous fishes, whose growth is more rapid than that of the bony fishes. It may be, further, that a bare skin lends itself more readily to the processes of assimilation. Or can it be that the process of feeding and that of digestion have dissimilar capacities? Here we are

coming upon one of the most intimate of all the actions accomplished by living matter, what is called its metabolism, for the elementary constitution of the creature is as much concerned in its creation as in its preservation. The assimilating behaviour is not, perhaps, the same in both cases. We see something of it and we measure its external signs, but we don't get much further, except in guesses.

" Moreover, your question, like every other question which is concerned with living nature, must be supplemented by a series of others. To be complete, it must go back to the earliest beginnings, and not stop short at this relation between a certain structural condition and a capacity for growth. It is by no means unimportant to observe the spontaneous, precocious appearance of this change in the scaly structure. The organism produces it by itself apart from any other influence. Environment has nothing to do with it. Your carp themselves make it perfectly plain that whatever variations there are arise directly from the creature itself, that they are accidental mutations, intrinsic in the first instance, then brought by it, for purposes of its own existence, under the control of the factors of the environment which allow it to live. These factors either refuse them or accept them. According to the particular case in question, life becomes restricted or settles down to conformity to circumstances. Actually, the adaptation is a compromise determined, after the event, by the automatic play of the relations between the creature and its environment."

" But what compromise," said my friend, " do you find in these scaleless carp? They seem to me to be under a definite disadvantage, since they have no protection. It seems to me that they are very badly off, whereas the carp with scales are much better provided. Yet the least favoured seem to be the most prosperous, while those which are better equipped, those which

have a complete mantle of scales around them, remain on a lower footing so far as growth and general well-being are concerned."

"That is because we form wrong judgments of the things of nature when we judge them in our own image, and as if they had feelings like our own, or else by taking into account a few particular examples and leaving the rest out of account. Nature is immense; in many ways she goes far beyond our own bounds and limitations. She has resources which we have not, and sometimes have no idea of. We are only too ready to imagine that every vital action has a specialized organ to itself, a tool as it were, judging by our own method of behaviour, for we spend all our industry in trying to devise tools fitted to our purposes. We begin by noticing that a great many fishes have a covering of scales, and this, we suppose, must be a protective covering. Then our minds decide that the two ideas must be closely connected, that of the presence of a scaly covering and that of protection, and finally arrive at the conclusion that one is the necessary corollary of the other. And when we do this, we are simply begging the question.

"You have seen your scaleless carp: they are as well protected as the rest. You did not find any break or tear in their skin. It is protected by its thickness, by its compactness, by a more abundant secretion of mucus. The creature which has no scales, brought face to face with the environment from which it must secure the elements of its existence, has made the necessary accommodations to circumstances by its own means. It has made the necessary adaptation as its innate condition befitted, and the harmony thus established, although it is not that of the carp with scales, is none the less assured. Extend this reasoning of the scales, continue it further, apply it to every type of organ, every function, every kind of being, and you will find that it always holds good, and that

it provides the most effective method of getting in touch with reality. Life in nature has at its disposal several implements and different modes of operation for every action that a creature must perform, and these vary in different living creatures. The organ and its function are associated only as a secondary consideration; they are connected rather by a sort of choice following upon structure and use rather than by a definite arrangement that has always existed and is indispensable."

"Right!" said my friend, rising, "and now we are concerned with a choice which, for once, is a matter of obligation. We have to dine in good company. These fishing days are days when we are favoured with the company of quite a number of guests. They will be here in a minute or two and I don't wish to keep them waiting. There can be no doubt that when we find ourselves at table with them before a good dinner and with several of our carp in front of us, it will be a choice dictated by our ideas of good food which brings us together."

CHAPTER VII

THE SHARK'S TEETH

FISHING for dog-fish, for giant shark! The story has been told over and over again; it is found somewhere in nearly every book of travel. In fact, it has become so hackneyed that it seems to have become part of the amateur writer's stock in trade. We all know its incidental details; there is the hook in due proportion to the size of the monster, the bait made of a huge piece of fat, the distrust shown by the fish at first, conquered at last by the gluttony which drives it to its fate. And we know the end of the story. The shark, victim of its own rapacity, is hooked, hauled on deck, and there deposited, still leaping desperately about and showing every sign of life. Everybody goes into ecstasies about its huge length, which is, of course, several yards. Everybody is terrified by the enormous mouth with its formidable array of sharp-pointed teeth, which opens and shuts in the convulsive struggles of the creature, as though to show its armament the better and create a stronger impression. Everybody on deck gathers round, taking care to stay at a safe distance and keep out of the way of the lashing tail and the desperate leaps. Finally one of the sailors cuts off its head with an axe, and disembowels it. The stomach and intestines are opened to see what there is in them and to discover what the monster had been eating before it was caught. Usually, besides a mass of half-digested fish, there are found various objects that had fallen from the ship. At last the remains of the "monster" are thrown overboard, and other sharks hasten to take advantage of the

offered meal, dashing up and seizing upon the dismembered fragments, being, like most other fish, not free from the reproach of cannibalism.

Scenes like this, the relation of which is only too apt to become a shade sensational, especially when a shipwreck is brought into the story, used to be common enough in the days of sailing ships, in voyages over tropic seas where sharp-toothed sharks are commoner than elsewhere, although they are to be found everywhere. Stretches of calm, often lasting several days, held the ship almost stationary. The refuse thrown overboard attracted all sorts of fish, sharks among them, and all hastened to make a good meal. But the sharks being bigger and more powerful than the rest, drove off their rivals, having the field ultimately to themselves. From the vantage point of the deck the passengers could follow their various movements and manœuvres; all round the ship, at one time or another, would rise the enormous heads, with bright shining eyes, broad strong-toothed mouths, fins beating rapidly. And it is not surprising that a certain sense of uneasiness was produced by the sight of them, especially when we consider that the passengers knew that they were far out at sea, surrounded by these creatures, with nothing but the planks of the ship's sides to protect them from a host of devouring monsters. Whenever one was caught, not only was a diversion caused, but a certain sense of relief. Nowadays, when ships proceed swiftly to their journey's end, there is not so much reason for excitement; the motive for it no longer exists, or does so only in unusual circumstances. There is not the same opportunity during a voyage for the entertainment afforded by shark-fishing.

But sometimes, quite as often as we care to, we may still see one of these great fish on our coasts during the bathing season. It is the same season as that of the sardine, mackerel, and tunny fisheries. These fish come near the shore at that time, and the sharks

follow them in the hope of feeding on them. They too are sometimes caught in the fishermen's nets. Often, thanks to their tremendous strength, they manage to tear their way out of the nets, but a good strong mesh will usually hold them. Sometimes the fisherman makes use of them for show purposes, if they are specially large; sometimes he sends them to the market where there is a good sale for their flesh. It is known as "white tunny", and tastes rather like that of the skate.

These common sharks belong to several genera. There are little ones like the dog-fishes, spiny and otherwise, and the topes, which vary in length between three and six feet. Their behaviour, shape, and customs account for the nickname of dog-fish which is often applied to them. Others, like the porbeagle and the blue and grey sharks, are larger, sometimes reaching sixteen to twenty feet in length and weighing many hundreds of pounds. When we see them stretched out on the beach or on the jetty of some fishing harbour, although they are lifeless, we may still feel, at the sight of their power, size, and especially the appearance of the great pointed teeth with which their jaws are armed, an impression like that which the ship's passengers must have felt after a capture in the open sea. We remember what we have heard about their prodigious appetite, an appetite that is never satisfied. And the impression will certainly be strengthened when we gaze upon the means employed by the creature to slake its ever-insatiable desire for food. We understand why the word "shark" has become the proverbial symbol for a greediness that knows no bounds, for an unscrupulous mind that will spare nobody and nothing in its search for satisfaction, that has no law and obeys no scruples.

In the sea the sharks are the counterpart of the panthers and tigers in the jungles. And they are very similar to those counterparts. Both have a voracious

appetite and hunt down their prey with unrelenting vigour. Both have the same terrifying armament of strong pointed teeth, the instruments and weapons which assure their dominance. Both have the same agility, the same vigour, the same behaviour as regards their victim; they kill to eat, to live, and in them unceasing slaughter becomes a sort of vital duty. In this respect the shark has an advantage over the tiger. It is more powerfully built; it is keener after its prey; and it has all the mysterious possibilities of its home in the depths of the sea.

Paleontologists tell us that sharks were among the first vertebrates to live on the surface of the globe. They came before almost all the rest. Fossilized traces of them, teeth from their mouths, spines from their skin, are found in rocks of the Palæozoic era. In them and for them the tooth makes its appearance among organs, and is adopted, as it were, by Nature. Nothing of the sort is found in creatures existing before them. The results of research in comparative anatomy and embryology confirm those of the palæontologists. To observe such a course of events and such a result in the creative progression of living beings is more than interesting. Nature, by such acts as this, seems immoral and barbarous. Why, with what aim in view, in what regard, has Nature produced at one fell swoop, of her own volition as it were, such instruments for bloodshed, such engines of carnage and destruction? Why, when producing life, did she create these mighty instruments of death? By what necessity was she driven to such a course? The mind hesitates and stands still before painful contradictions of such a sort, seeming, as they do, so inopportune and wrought with suffering. It does not know what to think, or at what conclusion to arrive. Is Nature, which seems so well disposed to all creatures, really the contrary; beneath the peaceful, restful mask she shows us, does she hide a very different countenance?

one can fail to remark the elasticity of the skeleton, built up of cartilage instead of bone. We see how extremely agile the creature is, its suppleness greater than that of other fishes, and when we examine the enormous flapping oar with which the body ends, we understand how it manages to swim so swiftly. The large sharks move even more swiftly than the tunny. Yet, when we go over the points of the shark, we are brought back, even in spite of ourselves, to its supreme features, the mouth and teeth, the characteristic outfit for dealing out death and destruction.

The mouth is found under the head, not at the end of it. The huge, conical snout sticks out in a compact mass and seems not to possess nostrils at the end. There really are nostrils, broad and full enough, capable of ensuring that their possessor can scent his prey afar off, but they are tucked away underneath. The mouth is not far behind them, crescent-shaped, stretching from one side to the other of the lower part of the head, and seems like a great gulf, so huge it is when the jaws are fully opened. That of the shark I examined might, when wide open, have permitted the passage of a whole man; and the trunk was so large that it would have taken the body from head to feet. On each jaw this monstrous mouth has a long row of large compressed triangular teeth, finely sharpened at their edges and all alike, which fill it completely and form a sort of double portcullis with fearsome prongs opening and closing like giant nippers. The tiger has only four canines, four teeth well fitted for the job of tearing and biting; the rest are shorter and not so powerful. The shark's teeth are mostly all alike, and all of them are capable of doing their job. In this fish the armament of teeth reaches its highest perfection, and that this may be assured, that it may always be able to fulfil its purpose, each part of it has a reserve or substitute tooth behind it, in case it should be broken and fall out.

These teeth are strong and solid; they are made of ivory covered with a strong, glistening enamel. But the base of them simply rests upon the jaw-bone, without fitting into a socket, so that it is not so firmly implanted. And even if there were sockets, they would not furnish any particular added strength be-

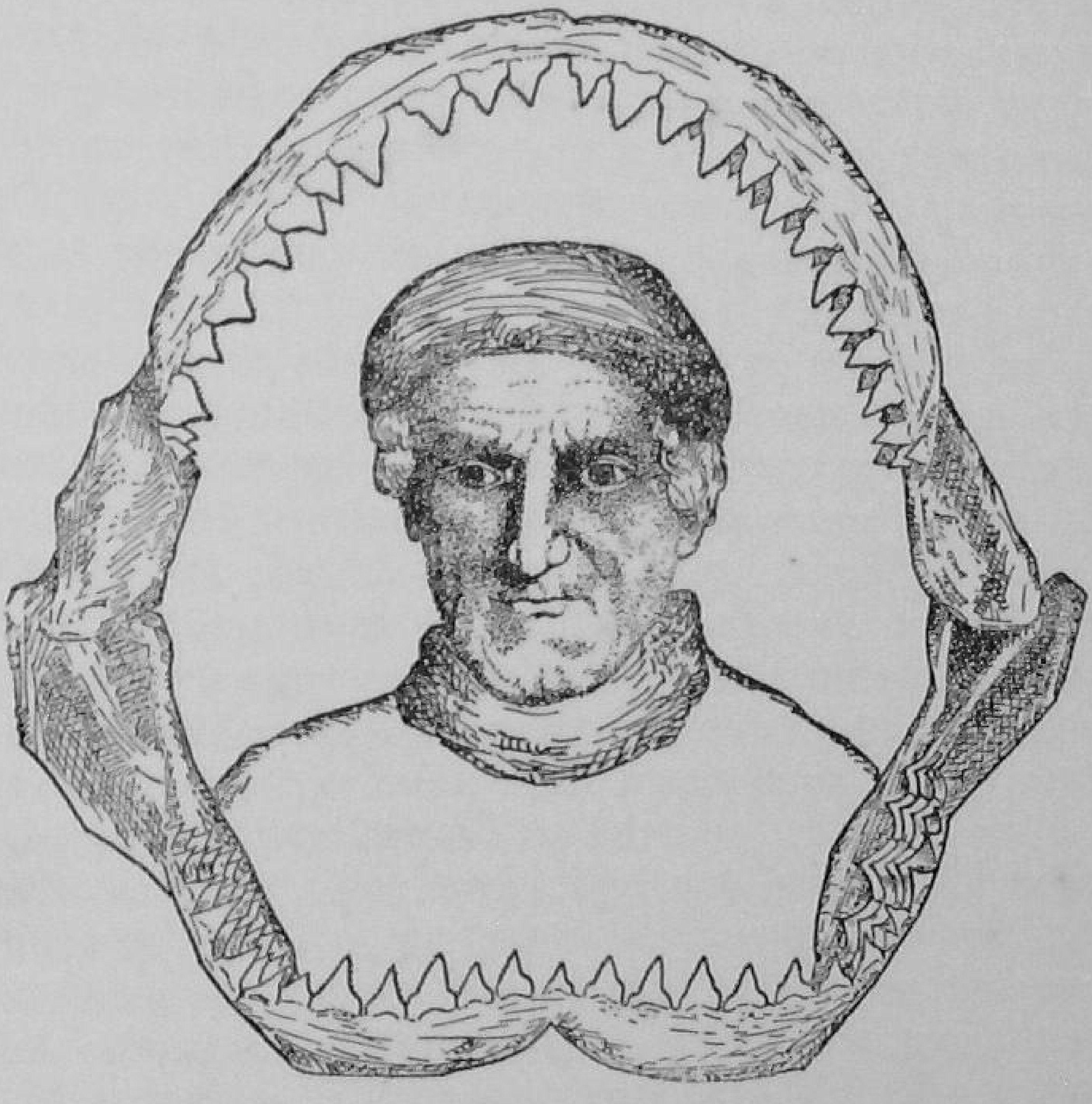

FIG. 19.—Jaw-bones of a large shark. The scale is indicated by the bust of a sailor drawn within them.

cause, since the skeleton is made of cartilage, its hardness would not be so great as that of the teeth. In naturalists' shops sharks' jaws are often to be seen with the teeth attached, and the difference between the strength of the teeth and the weakness of their support is always strikingly evident. We are inevitably reminded of the idol with feet of clay; there is a limit to the creature's capabilities.

However surprising this may seem, there is a reason for it. Despite an organic strength not surpassed by any vertebrates on land, the sharks display some traces of their earlier condition. The whole of their inner skeleton is made of cartilage. Bony tissue only occurs in the skin, reinforcing and consolidating the material of the scale-like denticles with which it is covered; it supplies the ivory, which, coated with enamel, gives the rough skin its firmness and hardness. The shagreen used by cabinet-makers for polishing is nothing but the skin of certain kinds of shark, specially prepared and fitted for its particular purpose because of its roughness.

The teeth are projections of the same sort, composed of the same material, and different from those of the skin only by being larger and occupying a more specialized position; they are definitely fixed at the entrance of the mouth. The mucous membrane round the mouth cavity or on the lips has the same origin and the same essential constitution as the skin which covers the body; it too is able to produce exactly similar structures; it forms them and, because of their peculiar situation, they act as teeth. This is true of all vertebrates, whatever they may be; their teeth, despite their appearance and function, are neither more nor less than skin structures. In that sense they belong to the same category as scales proper, feathers, and hair.

Having got so far, we arrive at our first conclusion. The shark, lying on the pebbly beach after being landed from the fisherman's boat, may display its fine set of terrible teeth as much as it likes. When we come to examine this alarming spectacle, we find that it is only an exhibition of weakness. It falls to the level of a mere ornament. As such, it is imposing enough, and when its possessor is alive in the water, it is free to exercise the prerogatives such an instrument confers, but, by itself, it by no means bestows upon the

fish a capacity as great as it might seem. Although it has its part in securing nourishment, the part it actually plays is not up to its apparent promise. This we found when we came to examine the contents of our shark's stomach.

The shark was disembowelled and cleaned without delay, and in its stomach, still intact and together with several partially digested mackerel, we discovered a tunny measuring nearly a yard in length. In spite of its dimensions and shape, this tunny had been swallowed whole; the teeth did not chew it, or cut it into pieces; they did not even touch it; there was not a mark upon its skin. It was just a single mouthful. The principal task of the shark when feeding is not to masticate its prey, but to snap it up directly and swallow it whole. The teeth are only an aid; they serve to hold a slippery, wriggling victim which is trying to escape, occasionally perhaps to cut a mouthful from a body that is too large to swallow entire.

Men engaged in pearl and sponge fisheries know this well. Often, as they go about their daily work, they have to protect themselves against the attacks of the great sharks. Experience has shown them that their enemy seeks rather to swallow them whole than to bite them. This they try to avoid, first, by getting above him and thus compelling him to turn over. This movement allows them a first respite, because his mouth is under his head. Then, if armed with a knife, they try, by swimming, to keep behind the mouth and so avoid being seized; then, by clutching a fin, to get near the belly and stab the creature in the heart. But such adventures seldom happen. The sharks, especially those of medium size, do not often trouble about human beings, because they are too large to be swallowed at a single gulp. In tropical countries we are not a little surprised to see natives bathing and diving in shark-infested waters, without being disturbed by their dangerous neighbours.

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There seems in this case to be a certain degree of disproportion between structure and function; the former providing an outfit beyond the needs of the latter. The creature could if necessary (and often does) do without such an armament. We begin to feel that, if there is no disharmony, there is at least a certain inequality, a mutual independence, which does not cause them to be entirely bound up with one another. If we pursue the study further, and extend it to all the known families of living and fossil sharks, we are still more driven to this conclusion. We see that the function makes use of the organ but does not, by any means, create it. The argument which

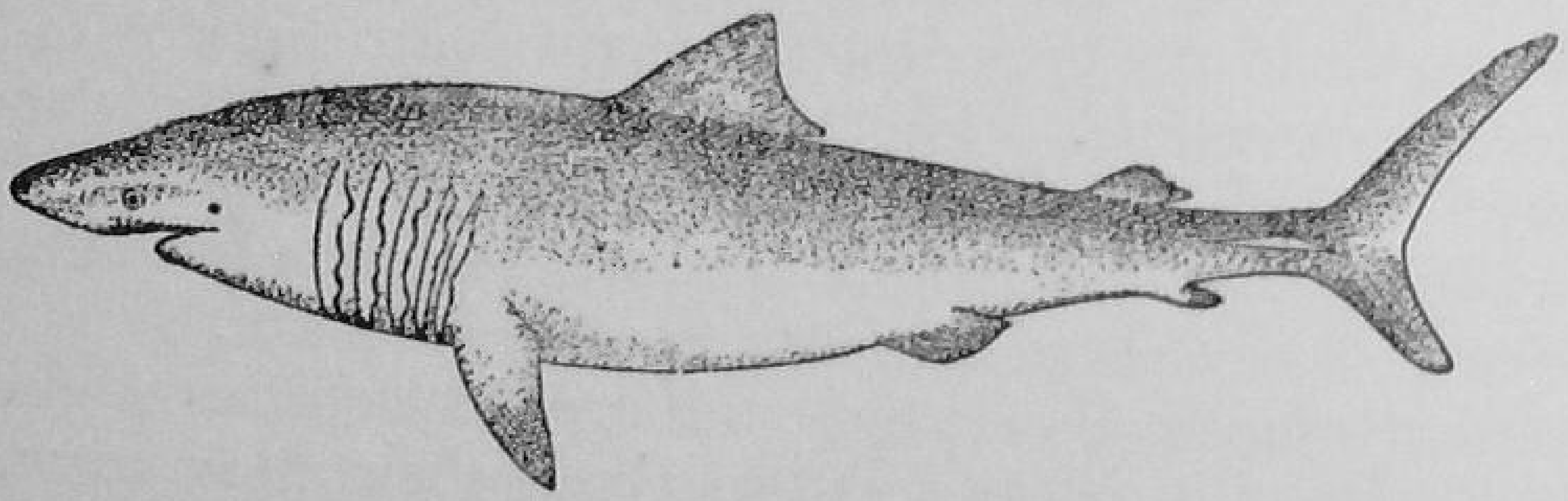

FIG. 20.—The Basking Shark, which may be as long as 35 to 40 feet.

we have constructed concerning the teeth is only a continuation and a completion of that which we built up around the scale.

The porbeagle of our waters are sharks of considerable size, and large specimens are sometimes as much as sixteen or twenty feet long, including the tail. But sharks of an even larger kind are occasionally caught both in the Mediterranean and the Atlantic near our coasts. These are the "basking" sharks, to which French fishermen have given the name "Pelerins" or "hooded" sharks, because of the appearance on the sides of their broad necks, covering the large gill-slits, of several folds of skin, like those of an old-fashioned cloak, superimposed one over the other. These fish sometimes measure thirty or forty

feet in length, and are correspondingly broad; their girth being sometimes more than thirteen feet. These huge monsters, which are almost as strong as the strongest whales, have a mouth whose size is in keeping with their proportions. This, like that of other sharks, is placed underneath the head, which ends in a great snout. But in size they are equalled and even surpassed by the whale sharks, which, contrary to the usual rule, have mouth and nostrils in the front, though they are as large as usual. These massive giants are fearful to look at, but they are practically harmless. They have size, weight, muscular vigour, and a mouth of large size but almost devoid of teeth. The jaws of the basking shark, in proportion to the size of the creature, are furnished with minute teeth, several thousands in number, but only a few millimetres in length. And when we come to the whale sharks, the state of affairs is even more striking: the teeth are more like the roughness of a file: to all intent, indeed, these sharks are toothless.

So these enormous sharks, whose greediness is no less than that of their smaller allies, have to secure their nourishment without the assistance of the more complex and powerful dentition possessed by the others. The capacity to snap up their prey is sufficient for them. The creature's swiftness, which allows it to overtake most other animals of the sea, and the breadth of its large open mouth, provide it with all the necessary facilities for seizing and swallowing in one gulp.

When we consider this deficiency in the outfit of teeth we might think it a case of transformation through falling into disuse, that is to say, by a gradual lessening or cessation of use. As the function becomes less necessary, the system whose business it is to accomplish that function is correspondingly reduced. If this were so, there would exist a formal relation between the two, not independence. But Nature herself shows the error of any such presumption. We must note the restric-

tion, but in contrast to it we must also note complications and superpositions which denote, in her general action of creating life, a variety and superiority of methods far greater than we could possibly imagine.

The strong triangular teeth of the porbeagle, which we also find in other members of the family, such as the blue shark, are only one type of this dental outfit. There are many others, and their diversity is surprising. Sometimes, the teeth differ in form in the two jaws: one set being conical, and the other flat, with a cutting and notched edge. In certain fish, like the smooth hound, a kind of dogfish, these teeth, instead of pointing upward, turn downward, and lie in plates set side by side, like paving stones. Certain species of skate, which are related to the sharks and in which similar facts can be observed, show an arrangement varying according to sex or age. And finally, certain sharks, now only found as fossils, which peopled the seas of the late Palæozoic era, had teeth in their jaws which had crests, corrugated, twisted, spiral, looking almost like the folds and convolutions which were found in several large reptiles of the Mesozoic era, and are still to be seen in the ruminants on land to-day.

If we go outside the group of sharks and skate, we find in other fishes similar dispositions, which go to prove the same absence of a relation between organ and function. Some predatory species capable of attaining a great speed, like the tunnies, have small, short teeth, while other species of a more sedentary type are better supplied, although they do not seem to have the same need. In fresh water, two different fishes, the trout and the bleak, have much the same mode of life and the same prey, but while the former has teeth, the latter has toothless gums, or pharyngeal teeth only at the back of its mouth, at the entrance to the pharynx, and these afford no aid in snapping up the victim in deep water. The bright-hued wrasse has two sets of teeth, one on the jaws and one in the

throat. The latter are sometimes called gill-teeth, because they are attached to the gill-arches, those bony structures which support the organs of respiration, and these branchial or pharyngeal teeth have varied conformations which help in classification. Their structure and arrangement recall those of the buccal teeth, although they themselves do not seem to have any particular purpose, either as regards the taking of nourishment or in the respiratory act itself. So far as teeth are concerned, there is every evidence of a wealth of creative power whose importance strangely exceeds that of the part—important certainly, but without much variety—that they have been given to play.

For this is where we seem to be arriving at a conclusion. It is with another eye that I now regard that huge shark's body stretched out before me on the jetty, and its alarming armament of sharp-pointed teeth. This mighty beast of prey is not simply a slaughter-machine, created by an evil Nature for the especial purpose of bloodshed, and equipped by her with that one aim in view. The equipment has no such purpose. The teeth were not made expressly to tear, and the function did not create the organ. The animal is content to use them when it possesses them, just as we make use of a tool when it happens to be at hand; but this tool was not specially brought into existence to render that particular service. If we think the contrary, as we commonly do, we are interpreting Nature far too much by our own standards. Our limited capacities compel us to make tools for definite purposes. It is not in us to imagine producing indefinite apparatus of every kind and every description, and then to choose from the storehouse that which best fits each particular case. Such a creative fancy is more than we can credit. But it is not beyond the powers of Nature, which, in its fundamental action, creates continually, fashions persistently, and never

ceases to produce something new. Then, from all these novelties, life makes a choice, and makes the best possible use of them for its diverse functions.

Snapping up a victim in deep water is a simple operation. The shark, dashing along, has only to bear down, opening its mouth wide, and it can swallow everything at one gulp. The teeth act as hooks to prevent the prey from slipping away: only in certain instances do they act as cutters. Their function is comparatively simple. If that was all they were for, their shape would take one form only, in due relation to their purpose. But this is not the case, since, despite the unity of function, we find an astounding diversity in the way the teeth are shaped and fitted in the various genera and families of sharks. In them we find a complementary principle of diversification which, having no connection with the function itself, is bound up with the nature of the creature, and depends upon it alone. Even if we agree that the function can create the organ, we are forced to admit that it does not govern considerations either of form or state.

Natural History, without degrading itself in any way, can content itself with describing what it finds out, and going no further. But the human mind, even the most realistic and concrete of human minds, always desires to go beyond present facts and find out what lies beyond them. In the labyrinth of things discernible by the senses, it seeks the guiding thread and, when it believes it has found it, holds on to everything that appears, reasoning in accordance with what it is accustomed to experience. We have needs, and we make tools to satisfy them. And so we are apt to think that the living Nature is in exactly the same position. Nature, we say to ourselves, has needs manifested by functions, and she creates tools in the form of organs expressly to accomplish them. When we reason in this way we forget not only our

weakness and our insignificance, but also our inability to escape the necessity of applying our productions to their use. Since we feel this necessity so keenly, we yield to it whole-heartedly and then imagine that it must be so with Nature, despite Nature's greater vastness and multiplicity. And when we do this, we bring Nature down to our own level, whereas real thought ought to consist in raising us up to hers, and in trying to understand her as best we can.

This is all metaphysics, I shall be told, this trying to go beyond the everyday realm of patent facts, in an attempt to find a new realm, a more general order, in which we may see the relation of things more completely. These appeals to the indiscernible, I shall be told further, have a certain praiseworthy merit, but they are also dangerous, as is proved by the number of odd and antiquated theories with which the history of the natural sciences is filled. This is true. Nevertheless a certain qualification must be made to this judgment. We are not dealing in metaphysical concepts simply because we admit the presence in living matter of a constructive power, always effective, which is capable of ceaselessly producing new arrangements, so that creation, instead of being considered as finished, may be regarded as still going on. This creating principle, this property of *forma formans* inherent in substances endowed with life, is their main attribute, their special kind of energy. We see it at work. To discover its existence and to make it known is not to go beyond the confines of legitimate thought.

We seem to be a long way from our shark's teeth, but they are still pertinent. They have supplied the basis for this generalisation, which continues and completes that of the scale, recommending us, if we wish to get at the truth, to overturn valuations which are only too often arrived at without sufficient reflection. As a matter of fact, there is no such thing as creation by use, nor making perfect by using, nor the dwindling

of a structure as a consequence of cessation of function. Independently of the part it is to play, the organ is created, shaped, augmented, by the formative, interior energy proper to living matter. No, the needs of the animal will make use of the organ if possible, or it will dispense with it if it cannot do so: but this utilisation after the event, so to speak, however perfect it may be, however adequate in relation to its object, must not hide the origin itself—the active, fundamental power of life in its incessant process of creation. By themselves, of themselves alone, use and disuse create nothing, eliminate nothing. The function does not create the organ: it can only mould it to its requirements. The cause for the building up of the organ, and of its progressive improvement, is to be found elsewhere.

CHAPTER VIII

PROTRACTILE MOUTHS AND DIFFERENT WAYS OF FEEDING

So seldom is the adjective "protractile" used in everyday language that we must explain its meaning. However, the etymology is simple. As applied to the mouth of fishes, it means that the jaws can be moved forwards and then withdrawn. The John Dory may serve as an example of a fish with such a mouth.

I have described this species elsewhere, mentioning its compressed shape; the position it habitually adopts which makes it seem like the blade of a knife as it floats upright; the markings on its sides, and the story that the fishermen tell about it. But these are not its only peculiarities. There is one which I have not yet mentioned, but which deserves to be referred to here. I once took a dory that had just been caught. It was among a number of little anglers and whiting which had been taken by a fishing smack. It was still fresh and supple, and its eyes were bright. I carefully set it down on my table in such a way as to give it the natural appearance it has in life.

Lying flat in front of me, I have a fish which, in its natural state, floats in the water like a vertical disk. To give it the appearance of life I have only to tilt the piece of wood on which it is lying. Then it is, so to speak, on edge, as it was when alive. Above the trunk I spread out the first dorsal fin, which is broad and high, with long plume-like filaments which stream behind it and are the source of various common names given to the species because of their resemblance to the tail-feathers of a cock or other bird. I look at the large head, compressed like the body, with large eyes

in the upper part, and marked by definite bony excrescences. I see the closed mouth, like a long oblique slit turning downwards; when thus shut, the lower jaw comes against the upper like a trap.

I press with my finger somewhere about the middle of the lower jaw, thus opening the animal's mouth. Then there is a sudden change. As the lever is pressed, accompanying it exactly, the upper jaw and the surrounding parts move forward and stretch out above the down-bent lower jaw. When this has moved as far as possible; when it leaves the horizontal and begins to turn down, it has above it the covering made of the parts so projected, and the whole forms a long, broad tube which, prolonging the great head, amplifies the snout strangely and gives it an entirely new appearance. It is like a mask which has just been put on. Think of an ancient castle whose drawbridge, as it is lowered, takes with it the ceiling and walls of the gateway it protects, so that before anyone can get into the castle he has to pass through a tunnel. Then you have an idea of the general effect of the change produced. If I reverse the operation; if, that is, I lift the lower jaw by pushing it upwards, everything goes back as it was; the parts projected fold up again, and finally the mouth, again becoming an oblique slit, shows no signs of its extraordinary powers, which are denoted by the word "protractile," a very suitable word to describe the phenomenon we have just observed.

This mouth, unlike any to which we are accustomed, has two movements; it opens from top to bottom like any other mouth, but, further, it lengthens and stretches forward. Both movements work together, thanks to a construction which is different from the usual, and to explain this we must make a short incursion into the realm of osteology.

The two jaws of fishes, like those of other vertebrates, contain as a means of support two skeletal pieces called

the maxillæ. To distinguish them we call one the upper and the other the lower. These two pieces, although they seem to be unified, are made up of several parts connected and joined together. These are not completely coherent, and can consequently be more easily seen in fishes than in other groups. The skeleton of the upper jaw is made up of many parts. In mammals, in spite of its compactness and unity, it is made up of four parts, two on each side. These are the maxilla itself, and in front of it at the middle of the mouth, the premaxilla. Occasionally, as in man, the premaxillæ and maxillæ unite to compose a single bone, although formed separately during the embryonic stage of life. But typically the four bones are joined only by sutures. There are cases, however, where the premaxillæ are defectively joined together and to the maxillæ. When there is no cohesion, there remains a slit at the place where it should have been, and when this happens in man, we have the unpleasant and distressing malformation known as hare lip.

In the bony fishes, the premaxilla and the maxilla, instead of being always bound together in a single mass, fairly often remain independent, distinct to some extent, and partially set one before the other. So varying according to family, they come together at different stages, bordering the mouth, holding up the jaw, and supporting the teeth. Sometimes the upper edge of the mouth is formed by the one, sometimes by the other, sometimes by both together. Usually both are shaped like drumsticks curved in accordance with the contour of the mouth, in which, on each side, the premaxilla is situated above and to the front, the maxilla below and towards the back. This is the general arrangement, and we find it in the John Dory, but in this fish it is accompanied by a more peculiar conformation, on an entirely different plan.

I put side by side, for purposes of comparison, the

skull of an ordinary type and of a John Dory. At the first glance their profound lack of resemblance is obvious. In the former, the premaxilla, on each side, is small and reasonably regular in shape. In the

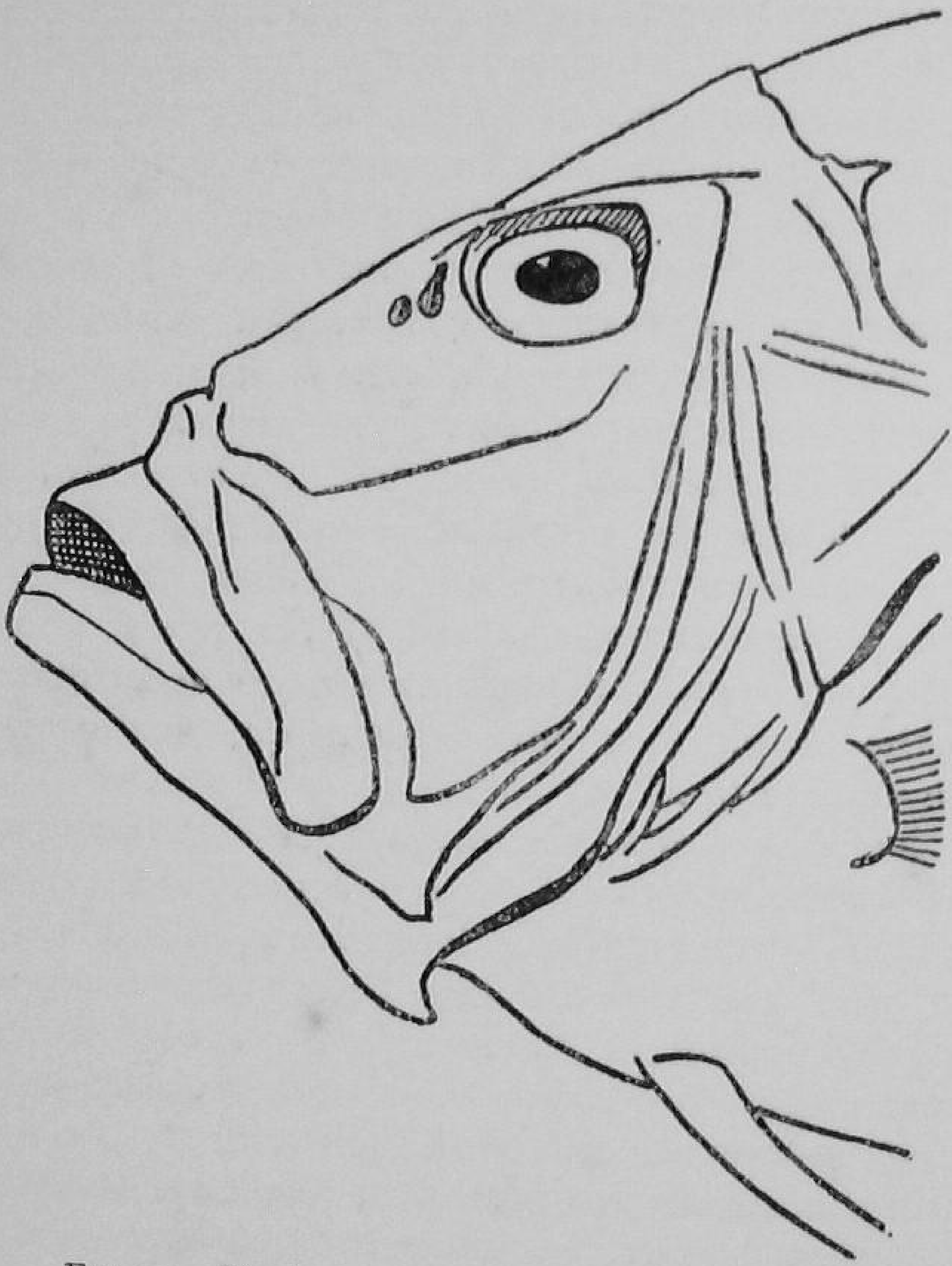

FIG. 21.—Head of a John Dory, mouth nearly closed.

latter, the premaxilla is a large bone wedged in, so to speak, showing two almost equally sized branches, one vertical and upright, bordering the mouth, with the maxilla behind it, the other horizontal and higher up, extending backwards as far as the orbit. The vertical branch is jointed at its lower extremity with the base

of the maxilla and the lower jaw. Consequently, when the latter drops to allow the mouth to open, it forces the upright branch of the premaxilla to come down in a forward swinging movement, and the horizontal branch, also coming forward, slips over the ridge of the palatines. The upper edge of the mouth, thus

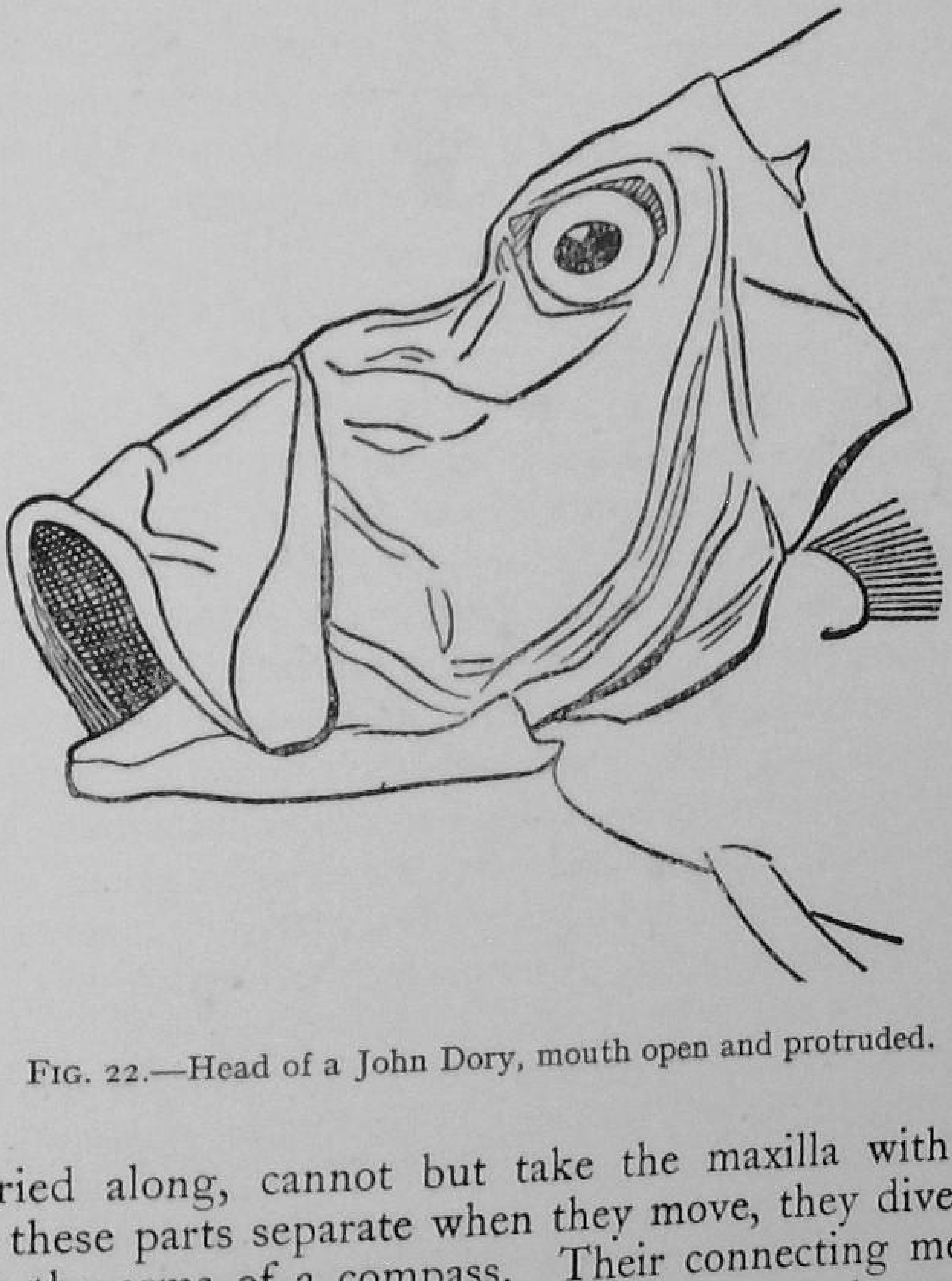

FIG. 22.—Head of a John Dory, mouth open and protruded.

carried along, cannot but take the maxilla with it. As these parts separate when they move, they diverge like the arms of a compass. Their connecting membranes spread out, but still fill the spaces between. The snout thus moves forward and projects, forming a spacious tube, opening outwards at one end, and allowing access to the back of the mouth at the other. When the mouth closes, the lower jaw rises and

compels the upright branch of the premaxilla to rise and fold back, the horizontal branch to slide towards the orbit, the various parts to come together and close up, and as the tube disappears with the closing of the jaws, there is only a slit-like orifice, a trap-like mouth, and the ordinary snout of a fish.

I carry out these backward and forward movements on a dead specimen, the thrusting forth of the tube and its subsequent withdrawal, and I pass slowly from one to the other the better to observe the successive stages. But what a difference there is between this slow operation and what happens when the creature is fully alive, swimming upright in deep waters. The projection and withdrawal take only an instant. Suddenly the creature opens its mouth—it takes no longer to do so than any other fish—and, at the same time, without any delay, the mechanism gets to work; its parts stretch out and separate and the snout is immediately formed into a large protruding tube. Then, with equal rapidity, the mouth closes; everything folds up, goes back upon itself, and returns to the normal position of rest. We cannot help seeing the resemblance to a mask. In the normal state, there is nothing of all this to be seen from outside. The mechanism is hidden behind a mask and appears only at certain moments. Then the creature presents an appearance previously unsuspected, and of which there was no sign.

This protractile mouth helps in the business of securing food. The large tube, thus projected, is used by the dory every time it wishes to seize its prey. Like other fishes, it opens its mouth to snap up its victim, but it does more than this; it stretches out the mouth and lengthens it, so that it can grasp the victim and seize it more surely. It has teeth too, but they are small and not many: they do not help it very much. The main part in the prehensile function is played by the mouth and its power of projection,

which enables it to act with greater effectiveness. A victim an inch or two away from the lips still closed, which might escape if they opened and closed in the usual way, finds itself encircled in this sudden darting motion. It is snapped up and swallowed, without possibility of escape. Here we find the highest degree of perfection in the method of securing food by the mouth.

The John Dory, and the fish of the same family, that of the *Zeidæ*, so called from the generic name (*Zeus*) of the dory itself, are not the only ones to be furnished with a mechanism so specialised, extraordinary, and so well adapted to its purpose. There are a few others, like the sand smelts, which are related to the mullet, and the Picarels, which are near relatives of the sea bream. Most of them are small; they are found on the coasts of nearly all seas, and belong to many genera and species. The sand smelts are often found near the shore in the Atlantic and the Mediterranean in the summer, often in considerable shoals. Fishermen catch them by the thousand. They are to be seen in heaps in fish shops, where their fine and delicate hue and their silvery glitter attract the eye, especially the brilliant band running down the side like a stole which has caused French fishermen to call them "priests". Their family, that of the Sand Smelts, has species of greater size in tropical seas, and their flesh retains the fine qualities of the smaller species of temperate waters. One of these is very highly valued in South America, where it has been called "Peje rey", the king-fish.

The family of Sand Smelts or Atherinids, Menids or Picarels, and Zeids, all have a protractile mouth. Although they are different in other respects, they resemble one another in this. All three belong to distinct groups of fishes. Their nearest neighbours either show no trace of this peculiarity or only in a very slight degree. Other species have a semi-protractile

capacity effected by a flexible connection between the skeletal pieces of the jaws which allows the lips to move forward slightly as the mouth opens. In the carp family, the carp themselves and the barbel have fleshy lips which can rise in a pout. But they have not the fully specialised mechanism. Indeed, since this mechanism is unique of its kind, it is remarkable that we should find it occurring in three distinct

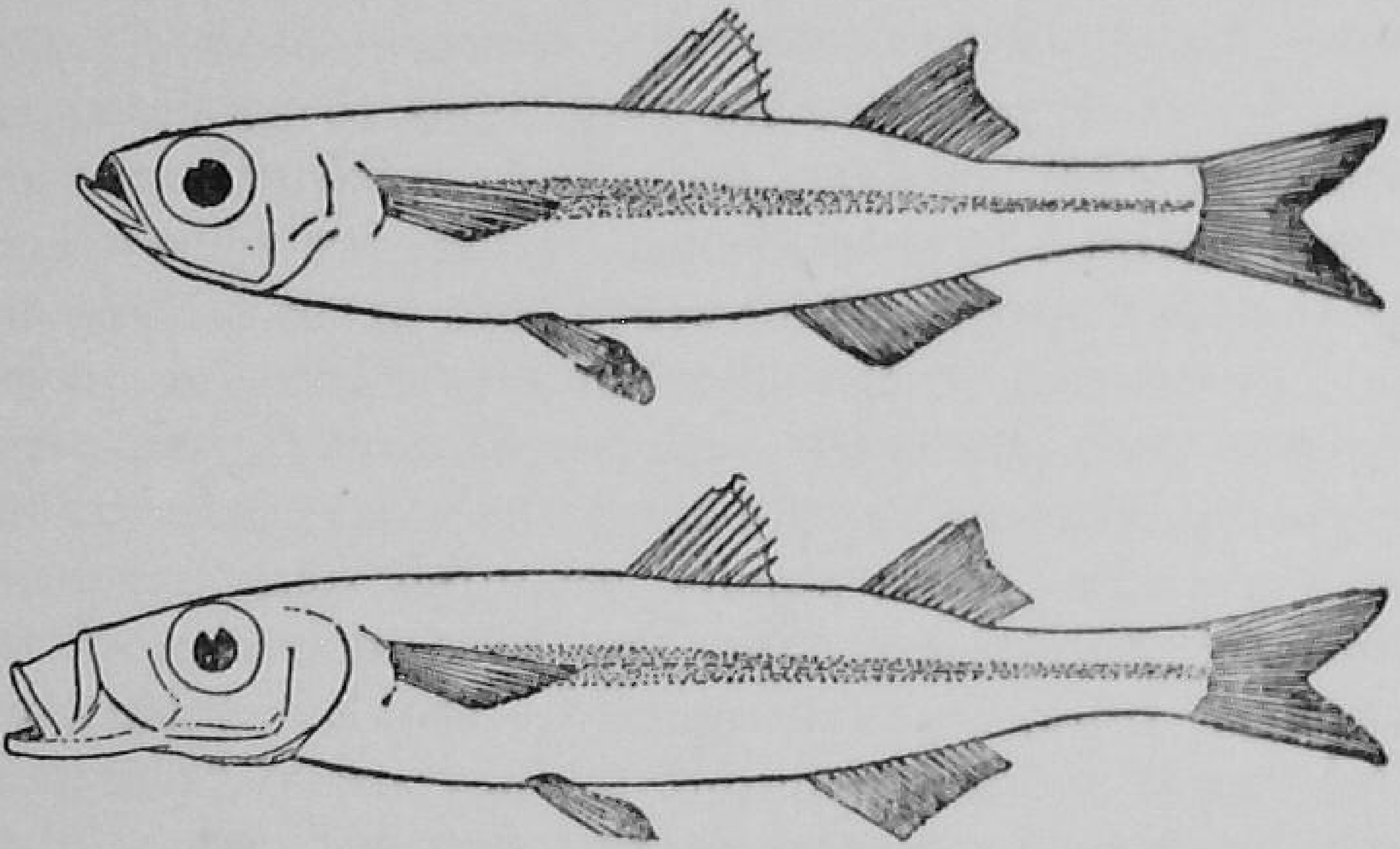

FIG. 23.—Sand Smelt ; above, with mouth nearly closed : below, with mouth open and protruded.

families which, otherwise, have no direct connection one with another.

The important function of securing nourishment is that which most forcibly compels the creature towards adaptation to its environment. It must eat to live. The behaviour, relations, and mode of life of the individual depend, in the first instance, on this necessity. So, if we seek to understand and appreciate the implications of the vital functions, we may well consider how this essential one is accomplished.

The simplest, or the most elementary, mode of securing food is that which works through the surface of the body. The water commonly found in nature contains

various salts in solution, several of which enter into the constitution of living matter. It also contains small particles of organic substances which are carried down by rivers from the land, or are directly formed on the spot by the decomposition of dead bodies. The automatic absorption of these substances is one source of nourishment, the weak degree of dilution being made up for by the extent and regularity with which they enter the system. This is practically the only means known to those microscopic creatures, unicellular animals and vegetables, which are held suspended in the water: they feed by means of imbibition of this sort. It may indeed be—and the suggestion has been several times put forward—that the same is true of larger animals, including fishes, and that the absorption of organic substances through the skin, even if it does not serve as a means of actual nutrition, acts as a sort of accessory to it. However that may be, the proportion of these substances is insufficient to assure the complete nourishment of animals with a complex structure. More than this is needed. Some form of solid organic matter becomes an indispensable article of diet. Then the business of securing nourishment assumes the importance that is its due. It is effected in very different ways in different creatures, and it is extremely interesting to watch the process going on in a large and well-filled aquarium.

The aquarium has its feeding times. At regular intervals the keeper distributes to his prisoners the food they need, which the restricted area of the tanks and the relative poverty of the water prevent them from finding for themselves as do their fellows living a natural untrammelled life. Sometimes, in fact fairly often, there is struggle and conflict. Even in this confined space, in this prison of glass, appetite is supreme. There are victors and vanquished in the fight. As is the rule in nature, the former devour the latter. That is only a fleeting episode. If the tank were left to

itself; if its captives were always alone with one another, the strongest would soon destroy the weakest, after which, since they themselves could find no more food, they would perish in turn. So they must all be supplied with food, and this usually consists of slices or mash of the flesh, cut up or minced if necessary, of various aquatic animals, fish, crustaceans, and little shell-fish. In the large public institutions of this kind, feeding takes place at regular hours, or under certain conditions. As one might expect, it has its regular attendants, and not without reason; the fish, excited by hunger, dash about in all directions, and show, perhaps more clearly than at any other time, of what they are capable.

The aquarium, which is a faithful reproduction of nature on a small scale, contains creatures of two kinds: those which are free and, since they can move in any direction, dash up to their food and snap it up directly, and those which are attached to the bottom or to supports, unable to move, and are thus compelled to wait until their food sinks down to them. These eat only by accident. Dependent upon chance, they are, for that very reason, all the more interesting to watch.

Among them we see various kinds of sponges. Some, spread out over different objects, bits of rock or fragments of shell, look like irregular incrustations, brightly coloured, the reds and yellows predominating. Others form inert balls, sometimes as large as one's fist and brilliantly coloured like the others. Attached to their rocky support, they remind us of the coloured globes which are sometimes put on a pedestal and used for ornament. Others stand up like little bushes, with nothing but their trunks and thickish branches. In spite of this diversity of appearance, the motionless character which long gave rise to doubts of their being animals at all, gives them a certain uniformity of behaviour and structure. Their surface is perforated by a number of orifices of different sizes, in one place so minute that they are hardly visible, in another wider

and easier to see. These holes allow entrance to the water which passes through them into a series of canals and chambers by which the whole of the creature's interior is traversed. There it continually circulates, entering in one place and going out in another, ceaselessly being renewed. This persistent imbibition, or perhaps we should say incessant irrigation, that goes on within the creature, brings to the sponge the substances it needs for breathing and feeding. The water contains oxygen in solution, and food particles in suspension, takes them along with it to the interior of the organism, passes them over to the living tissues; then flows away and gives place to other water, which carries on the action. This ceaseless renewing produces the required result.

Near the sponges, like them resting on fragments of rock, are the sea-anemones. These are more impressionable, less inert, and there is no room for doubt that they are animals. Their body is cylindrical, contractile, elastic, and stands up like a column well settled on its base. Sometimes it rises vertically and spreads out at the top; sometimes it contracts into a dome-shaped mass. The summit has tentacles gathered into a crown and surrounding a spacious mouth opening into a large stomach, the cavity of which occupies most of the animal's interior. When we come to consider it, the sea-anemone is little more than a stomach fitted with tentacles.

It is a curious sight. It cannot shift its position; it is fastened to the place in which it lives; its tentacles move, showing that it is possessed of reasonably acute senses. Sometimes they spread out uniformly, turning themselves outwards; sometimes they fall back inwards. Some of them lengthen, some shorten; they are almost incessantly on the move. The creature has the added attraction of exquisite, sometimes intense, coloration, the colours varying according to the species, brown, green, yellow, red, steel or spotted. It is not hard to

understand why they are sometimes called sea-anemones, sometimes " sea-roses ". The beauty of their brilliant colours, and the appearance of their tentacles like flower-petals, justify these poetic names. But when we touch and handle them, we may understand also the reason for another name which is not so flattering, that of " sea-nettles ", which is justified by the sensation of burning which may be felt when they are touched. These supple tentacles, sometimes the body itself, have in them a stinging apparatus which comes into play when the animal is touched.

The sea-anemones eat only occasionally. It is only by chance that food comes their way. It may take the form of some animal, a little fish for example, which swims within reach of their tentacles and finds itself captured. Then the tentacles all tighten round the victim, coming together about it like an envelope. They convey it to the mouth which opens wide to receive it, and so it passes to the cavity of the stomach, where digestion takes place gradually as the victim is brought into it by degrees. In this animal such a meal is a rare, an accidental, happening. Most often it must go without. Days and weeks pass without any victim presenting itself. I have known sea-anemones to live for several months in an unused tank without eating anything. The slight amount of nutriment provided by the water, which was always being renewed, was sufficient for them. They display, in a more striking manner than we see elsewhere, the remarkable power of resistance to hunger which all aquatic animals possess, fishes among them. Fish can survive for weeks without feeding; their own substance serves them as food, and they keep themselves alive though they grow thin and emaciated. The water maintains, if it does not nourish. In the world of waters there is a certain element of truth in the expression " living on hardships " which is so untrue so far as land-dwellers are concerned.

This infinitesimal kind of meal, supplied by the water

alone, is to be observed even more completely in other creatures, like the coral polyps, which are like the sea-anemones in structure, for they are a sort of small edition of the latter. They too have a large stomach, which is almost always empty, showing no effective trace of a digestive process at work. All are associated and bound by canals which go from one to another, and the water, coming from outside, circulates in all, renews itself continually, penetrates their common mass, irrigates it without ceasing, as in the case of the sponges. And this is enough for them. This continual circulation allows some of them to extract from the water the vast amount of lime needed in the production of their large polyparies, the heaping together of which forms islands and serves as a basis to parts of continents. We need not be surprised, then, that the water helps the growth and maintenance of these little quantities of living matter of which the colony is composed.

Besides the sponges and sea-anemones, the tank contains other creatures, like them fixed to supports and incapable of movement. Often these are completely motionless, but occasionally, and suddenly, they quiver and thus give an indication of their animal character. There are the Lamellibranchiate or bivalve molluscs, oysters, mussels and clams, which open and shut their shells, and put out or draw in siphon-like tubes, which they use for the intake and output of water. There are also the Ascidians, sea-squirts, which were among the precursors of the vertebrates. Attached to projecting parts of the rocks, or sheltered in hollows, they protrude their two gaping siphons. They continually pump in water at one siphon and expel it at the other, keeping a ceaseless stream passing through their bodies. Sometimes they contract and draw in their siphon-like tubes, but soon expand again, erecting their siphons once more, thus indicating that this circulation of water is a very important factor, and performs a function they cannot do without.

The water enters their organ of respiration, the gill-cavity, a large pouch which fills the greater part of the interior of the body. The inhalent siphon, which draws in the water, leads to the mouth, and the mouth opens into the gill-pouch, for this is nothing but an enlarged pharynx, which by its size is capable of dealing with respiration and nutrition. It is pierced by a large number of little openings, like a very fine sieve. The water passes through these orifices and, leaving the branchial or gill-pouch, is collected in another pouch which surrounds the first. The gill-pouch is like a cylindrical sieve contained in an outer sac, and this is fitted with a spout to empty it. This is the second siphon, which serves to throw out the water, and is called the exhalent siphon.

When this apparatus is in action, the water enters by the first siphon into the sieve-like pouch, filters through its many tiny openings into the surrounding casing, and finally flows out again. By this means a continual fresh current is assured. The agent which forces the water to circulate continually in one way is the beating movement of innumerable microscopic vibratile filaments with which the edges of the openings of the sieve are fitted. They all beat without ceasing, sweeping the water along, passing it from the interior of the inner pouch into that of the containing pouch, and so setting up and maintaining the circulation.

The interior sieve-like pouch serves a double purpose, for both feeding and respiration. In the first place it acts as a gill. In the framework round the holes perforating it there are blood-vessels, in which the blood, as it flows, gets rid of its carbonic acid and absorbs a part of the oxygen dissolved in the water which is continually arriving. It serves, further, as a means of securing food. On its inner face, it has a network of mucous strings, which form, as it were, a sort of sticky net, whose meshes cover the holes of the sieve in all directions. These strings catch up the

tiny food particles which the water carries along as it passes through. Many of these particles are microscopic floating creatures which, stuck and unable to get free, are captured. But this net is not absolutely fixed; the vibratile filaments which cause the water to circulate also carry its meshes towards the end of the gill where there is an orifice leading to the stomach. The meshes, carrying their tiny victims, direct the prey along the way to the stomach where they are digested, and other meshes take their place at the other extremity of the gill, so that this extraordinary net is always ready and in position, agglutinating and moving at the same time. With its assistance the sea-squirt catches in its own body the prey upon which it can feed, using in its own way this remarkable internal trap which would make any poacher green with envy.

These animals exhibit a remarkable conformation. It foreshadows, in an elementary way but still quite clearly, some structures which the vertebrates show in a fuller degree, and in greater complexity. They have the fore-part of the digestive tube serving also for respiration, a pharynx converted into a sieve-like gill as in the lancelet, an adhesive mucus comparable to sticky saliva. But the functional action, which enables the creature to keep alive, is even more extraordinary: the bringing into the body of a considerable mass of water drawn from outside, the continual renewal of this water, and its use as a carrier of food. Such a system is indeed surprising. Nature, in her effort to maintain life, utilises the strangest methods and yet succeeds in attaining her end.

These sea-squirts, eaters-of-tiny-scraps, feed upon microscopic prey. They are not alone in so doing. The bivalved Lamellibranchiate molluscs do the same thing: they feed upon little creatures which the water brings. But in their case the mechanism is different. Mucus-secreting lips, which surround the mouth, play an important part in securing it. The result is the

same. When we eat an oyster, a mussel, or a clam, we consume flesh that has been formed out of that of countless tiny beings, living suspended in the water, upon which the shell-fish has fed. And we in our turn feed upon them through this intermediary; we use to our own advantage a form of nourishment of which, otherwise, their very smallness would deprive us. These eaters-of-tiny-scraps thus have a value and a usefulness for us.

But does this mean that this somewhat scanty sustenance is all that counts in the nutrition of the individual? Hardly. During their whole existence, a volume of water, enormous in relation to their size, passes through these creatures. This volume is so great that the creature, like the coral polyp, finds in it oxygen to breathe and the calcareous substance of which its thick shell is constructed. Beyond doubt, it also takes other substances, and uses them for the maintenance of its living tissues. The coral polyp feeds like a sea-anemone and its microphagy is complementary. It is assured of a certain minimum of nourishment by the water which passes through it. We see this by the way it grows. If the food consists of microscopical particles only, the growth is slow, limited, and reduced to a minimum; if of larger substances, the growth is enhanced and even exaggerated.

In more complex animals like fishes, food on a large scale become the regular thing. The constantly renewed water serves for breathing but for little more. Fishes move from place to place, their muscles do work, and they need more frequent, more solid, more compact nourishment. Microscopical food would leave their needs incompletely satisfied. Creatures more mobile, almost always more powerful, need stronger and more numerous prey. They are, of necessity, macrophagous, eaters-of-large-morsels, which they must seize, cut up, chew, and digest. They are not necessarily superior as " beasts of prey " to the more modest

creatures, for all alike feed upon living substances, and the quantity of this food has nothing to do with the activities that secure it; but they exhibit those activities in a manner more sustained. They reveal themselves as predatory creatures, whereas the microphagous animals appear to hide their true nature. Many of the former assert the fact with vigour and assurance and develop new characteristics.

In another tank now before me are a few cuttle-fish, with oval bodies, heads with great eyes, and a circle of tentacles with suckers. They swim along quietly, undulating the fin which surrounds their sides, looking like creatures on the prowl, their eyes for ever on the look-out. When a possible victim presents itself, even if it is a large one, they seize it with their long tentacles, surround it, immobilize it, then cut it up with their powerful horned beak and swallow it in fragments. Near them in the same tank, lurking curled up in a corner, are octopuses or devil-fish, belonging to the same group in the class of cephalopod molluscs. They spread out round them, moving hither and thither, their flexible snake-like tentacles, waiting for some victim to seize upon. If some rash crab comes within reach, he is snapped up, enwrapped, held by the suckers, and, in spite of the hardness of his shell, cut up into little pieces by the chisel-like beak. In order to get their food, these devourers of large prey have special tentacles designed to facilitate that end. And the crabs themselves, with other crustaceans, have similar powers, for they use their claws to hold the creatures upon which they feed.

But this is not true of the fishes, whose fins are incapable, except very rarely, of performing any action but beating the water for swimming. As these fins cannot grip, they cannot help directly in the process of securing food. All they can do is to ensure a rapidity of movement which enables the creature to pounce upon its prey. The actual seizing is done by

the mouth alone. The rapid snapping carried out in a single movement, the sort of sucking action which may accompany it, make up the principal method, especially in deep-water fish. Usually, the teeth play a secondary part. Their appearance should not disguise from us that their presence, their condition, are often apparently in contrast to the masticating function we are tempted to attribute to them. Sometimes we find them strong and numerous in species that live on the bottom and feed upon dead bodies; sometimes we find them small and few in hunting species which would seem to have the more need of them.

The protractile mouth is an obvious improvement. In those aquatic creatures which have no prehensile organs, it makes up for their absence and, by its own effectiveness, enlarges the field of action. It takes on their duties while still performing its own. When the fish thus equipped opens its jaws, it projects them at the same time, pushes them forward, so extending the scope of the mouth considerably. This is a definite step forward of relatively rare occurrence, and we see it developed independently in different groups, just as in mankind we sometimes observe chance resemblances between unrelated individuals.

Things are different in land animals. The seizing of food by a sucking mouth is only known in a few instances and to a very limited extent. A new circumstance operates in their case—the force of gravity. The prey is too large and the mouth too small to permit of such a mechanism. There is not the surrounding environment of water to lessen the specific gravity. Then the prehensile organs and the teeth become functionally important, and we find a degree of specialization greater than that exhibited in other instances. The limbs effect movement, but they often serve to hold, or to seize, in addition. The muzzle becomes a snout. The jaws in birds and turtles become beaks. Tongues and salivary secretions, in certain

cases, share in the work of prehension. Teeth assume a dominant place, and, according to the group, seize, bite, cut up, or grind. Those of the carnivorous mammals give to the " beast of prey " which possesses and uses them the complete character which the name seeks to express.

When we regard the astounding multiplicity of structure designed to fulfil a single function, how unimportant seem the elaborate attempts to explain it. The only useful work the naturalist should try to perform is that of looking at Nature as she is, not as he supposes her. Eternally at work, he must try to understand her as a whole, try to look at her with eyes ever new and always open, not to be content with a restricted material vision which can be amplified by theories. Nature brings into harmony her countless subjects and allows us to realize some of the harmonies that she creates. But we must avoid considering them as being themselves alone able to express all her power, for they are only fragments of a whole unknown to us. To modify Pascal's saying, Nature has reasons of her own, which our reason knows only in fragments, and at odd moments. Before her splendour and her activity, imagination is but idle and powerless. If we are to know her, we must try to gather up all her fragments and prolong all her moments.

CHAPTER IX

THE POISON OF THE MURRY AND OTHER MARINE ANIMALS

For many years the murry has been credited with unpleasant characteristics; it has been notorious rather than famous. You may remember the story of Pollio, that extravagant and cruel Roman, who threw his slaves to feed the murry in his fishponds. Fish that feed on human flesh they have been considered ever since, and to most people that is all they mean today. The species to which they belong is none too common, at any rate in our part of the world and in temperate seas, and consequently is not often seen in the fish markets. If we are determined to find them, we must go to the Mediterranean. In warmer waters they are, however, much more common. To us, their very rarity, the mystery of that rarity, add to the tragic element that shrouds their name. So, in an aquarium, their tank has always many visitors. As soon as the label attached to it is noticed, there is a rush to see what these mysterious fish are really like.

There is indeed something about them which justifies the interest they arouse. In the soft light of the water, appearing from holes in the rocks, there emerge several delicately shaped brownish heads set on thick necks, with yellow markings. There is nothing more to be seen: the rest is invisible, hidden beneath the rock. These are the murry. Frequently, several of them live together in the same hollow, and their heads and necks all appear at the same time, some showing more than others.

They are all alike. A pointed, ferrety snout; a

large, half-closed mouth in which can be distinguished the fang-like teeth with which it is equipped; black, glittering eyes; an attitude which, despite its immobility, we feel to be somehow aggressive, give them a quarrelsome sort of expression and make them seem vicious. They do, indeed, look as if they deserved their evil reputation.

The placid-looking congers which are often to be seen in the same tank belong to the same group and obviously live in the same sort of way—but seem even more peaceful than ever, like a quiet little lap-dog beside a savage mastiff. The murry, although motionless, although only its head and neck are to be seen, is like a mastiff. We feel that it is on the alert, ready to bite.

This feeling is intensified, though its nature is slightly changed, when one of these murry leaves its lair and swims about the tank. Then we are surprised by its stoutness, the size of its body, the richness of its colouring. The slender, pointed head is out of proportion to the rest: the neck and the trunk are thicker. There is a breadth about it which we did not anticipate. If the murry resemble the congers and common eels as regards length and in the sinuous nature of their movements, they possess unusual strength and suppleness. They may lack the pectoral fins which others have: they may only have, on their backs and beneath their bellies, narrow folds in the place of dorsal and anal fins; but they make up for the absence of these locomotory organs by a flexibility which enables them to move through the water in serpentine curves. The murry is a magnificent creature, powerful, robust, far surpassing its fellow-eels in splendour and vigour.

It is an interesting sight to watch them, as they move about their tank. They advance, retreat, rise, and swim to the bottom as if gliding through the water, avoiding obstacles, extending and folding again their long bodies with supreme ease. When

swimming, they wind gently, almost lazily, about, and we cannot fail to admire every movement they make. Their body bends, straightens again with graceful movements, with elegant and ever varied curves. It undulates as it draws near: it undulates as it moves away, and finally goes back to its hole, enters it, and there resumes its accustomed attitude of rest.

The beauty of this creature, displayed in its supple movements, is enhanced by the splendour of its colouring. The murry, the panther of the seas, is clad in a glorious striped livery, of which the ground is a sombre red, adorned by patches of brilliant yellow, bespangling it like so many jewels. An iridescent garment, whose texture has a silky quality that no material could hope to rival; a livery so infinitely varied that, although all the murry in their tank possess it in common, they all differ in its arrangement. Our delighted eyes follow them unceasingly as they twist and turn. We keep comparing one with another, marvelling at such diversity in a perfect harmony of shades and tones.

What we see in the aquarium is a true representation of Nature, though, of course, on a reduced scale. In the warm parts of the Mediterranean, several fathoms beneath the rocky cliffs, or among the coral reefs of tropical seas, it sometimes happens, if circumstances are favourable, that we can see the murry down on the bottom, about their daily occupations. They behave there just as they do in the aquarium, in little bands, looking out of their holes, side by side. Some we see, and may catch, of an enormous size, from six to ten feet long and correspondingly broad, as big as large snakes, but thicker. Fishermen say that they sometimes come across even larger specimens and that, cast up on the sands of Arabia or India, huge murry have been seen, real sea monsters. It has even been thought that the mysterious legendary monsters we call sea serpents, which have been reported from

time to time, have been gigantic murry, or species of the same group, which have come up by accident to the surface of the water. Whatever may be their ultimate capacity for growth, the common murry is often a creature of remarkable dimensions, rendered noticeable and immediately recognisable by its long body and yellow dappled skin.

Despite the relative smallness of their heads, these creatures are well armed. The mouth, with its large cleft, has powerful, hooked teeth on both jaws. Moreover, attached to the palate, it has more teeth, even stronger than the others. Such a formidable array of teeth harmonizes well with their combative appearance. The murry look like creatures ever ready to take the offensive. On the *qui vive* in their accustomed lairs, keeping watch all round them, it would seem that, like the panthers which they resemble in colour, they will seize the first opportunity to dash out upon any unfortunate prey rash enough to venture within reach. As a matter of fact, they are not nearly so bloodthirsty as they seem. At times, it is true, the murry catch and feed upon the animals they can reach; but hunting is not naturally one of their strong points. They hardly ever hunt down their prey in the open waters. They are inclined, in fact, to be rather lazy; eaters of dead bodies and inanimate things: they enjoy the numerous crumbs that fall from the tables of the truly predatory species.

This laziness, the varied nature of their food supplies, an existence passed in the hollows of rocks washed by pure water, conduce to make their flesh excellent and finely flavoured; it is far more delicate and savoury than that of the congers and common eels. The epicures of the Mediterranean coast think very highly of it. Soup made of the murry, grilled murry steak, a grilled murry, in their opinion, are dishes fit for a king. So, in our own day, they carry on an old tradition. The ancient Romans also thought highly

of the murry's flesh. Having observed that they flourished in pools and fed readily upon odds and ends thrown to them, they undertook to raise them. Rich epicures had tanks near their seaside villas in which they kept them, together with other marine eels.

Thus it is that we come to hear the story of Pollio's cruelty to his slaves. Doubtless at a time of proscriptions and games in the circus, when a man's life counted for little, the same theme was only too well known. The owners of slaves, having the right of life and death over them, used to condemn to death those whom they wished to punish, and death by drowning was one of the simplest and easiest forms of execution. From this point it was not a long step to make it an occasion for feeding the murry; and this was in fact done. Whatever we may think of their behaviour, we must admit that these particular slave-owners found nothing disgusting in it.

Though the murry may be much esteemed by the epicure, the fishermen whose business it is to catch them are cautious and try to avoid being bitten. Although these fish show no keenness in pursuing agile prey and seizing them; when they themselves are approached they give evidence of a fierceness which is hardly noticeable at other times. On the defensive they are more desperate, quicker than on the offensive. Then they justify their evil looks and their formidable appearance. They try to bite even before they are attacked. Like other eels, it takes them a long time to die when they are taken out of the water, and this is due to the small size of the gill orifice, which enables the gills to remain moist for a long time. At the slightest touch they become active and dash up with mouths open, showing their fangs. Their bite is the more dreaded because it is deep, the teeth being so long. The wound they cause is extremely painful and takes a long time to heal, sometimes

setting up inflammation in the parts adjacent to the wound. The murry, in fact, is a poisonous fish.

This has been denied. If certain bites heal quickly, without complications, others are more painful and more serious, and although no fatal case seems to have been recorded, they give rise to alarming symptoms. Here, doubtless, we have evidence of differences of sensitivity and resistance varying according to the nature of the persons bitten, and probably variations and differences in the murry as regards poisonous capacity. But there is no doubt that in their mouths they have a mucus which covers also the surface of

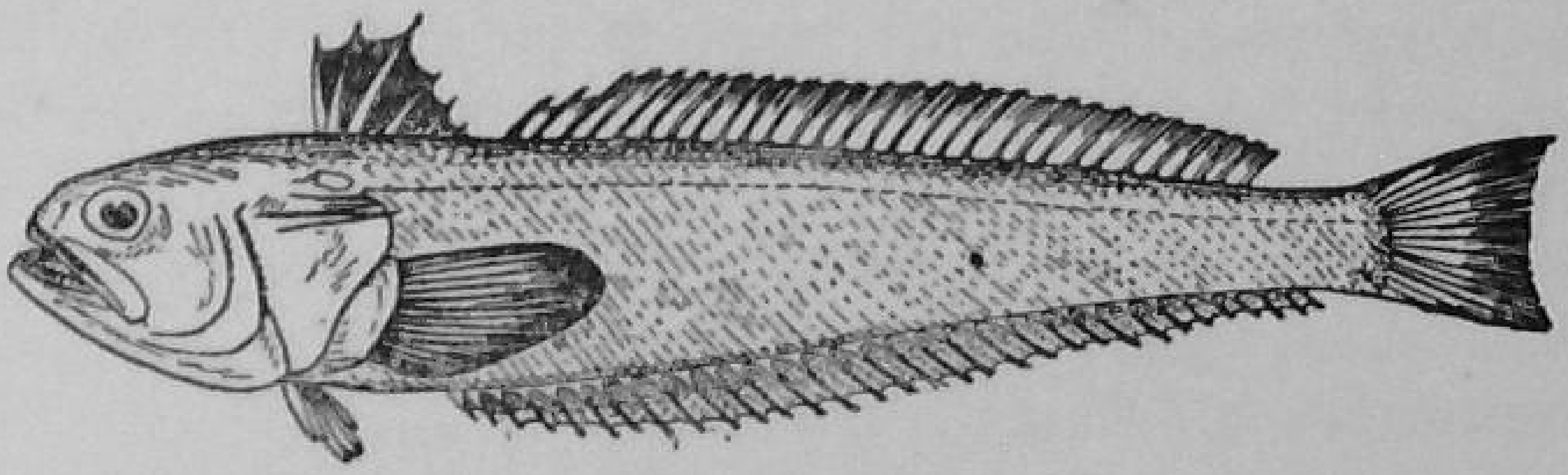

FIG. 24.—Weever. A poisonous fish which may attain a length of nearly two feet.

the teeth and possesses toxic qualities. When the creature bites, it poisons the wound it causes by leaving in that wound a certain amount of this mucus. Hence, the murry provides us with an example of a fish that poisons by biting, like the viper or rattle-snake among snakes. Its poisoning apparatus is not so efficient as that of the snakes, but it possesses the same essential qualities.

However, the murry is not the only fish to have such a power of poisoning. There are many others. Only, in these, the poison organs are usually spines occurring in different places on the surface of the body—the fins, tail, or gill-covers. Certain species, indeed, hog-fish, sting-fish, and whip-tailed sting-rays, have as bad a reputation as the murry them-

selves and are almost as much dreaded. Yet they only display, in an exaggerated degree, a quality which is possessed by most fishes, if not by all. Fishermen know that our fresh-water species, even the most ordinary of them, can sometimes cause painful and cruel wounds, if one happens to prick oneself on a fin or spur on the gill-cover. It does not always happen, but it happens often enough to show that there is a general cause, usually benign, but capable of being accentuated and intensified in certain species in certain circumstances or at certain times.

This cause arises from the accustomed condition of fishes. In many of them, the skin is covered with a slimy mucus which, attaching itself to the scales, covers the body with a protecting coat. This mucus contains in varying proportions certain toxic products excreted by the teguments. These products inoculated in a chance wound may set up inflammation. Sometimes accumulating in certain areas in greater quantity, they become associated with spines, and form a sort of poisonous apparatus.

This apparatus, however, serves only as a defence in case of emergency; it is a momentary means of self-preservation. The sting-rays when they lie buried in the sand bed, the hog-fish in their hollows among the rocks beneath the foliage of seaweed and grass-wrack, never use these poisonous stings to attack their neighbours, and not even to defend themselves against them. Their life usually is passed as if they did not possess such an armament, like that of fishes not so equipped. I see them in their tanks, looking like any other fish, showing no peculiar mode of behaviour. They possess such an organ, but as a secondary characteristic, often quite inoperative.

This is not exactly the case with the murry. The poisonous organ is in another place, the mouth, and for that very reason its quality is accentuated. Although, in the ordinary course of events, the creature does not

make use of it more frequently or to better purpose than other poisonous fish; although it only employs it for defensive purposes and in exceptional circumstances, this act of defence, which consists of biting, is a vigorous action contrasting strongly with the murry's accustomed passivity. The sting-ray stings only when it is handled, or when it is trodden upon. It would be fairer to say that it stings when we make it do so, for otherwise the animal remains passive. The murry, on the other hand, deliberately bites

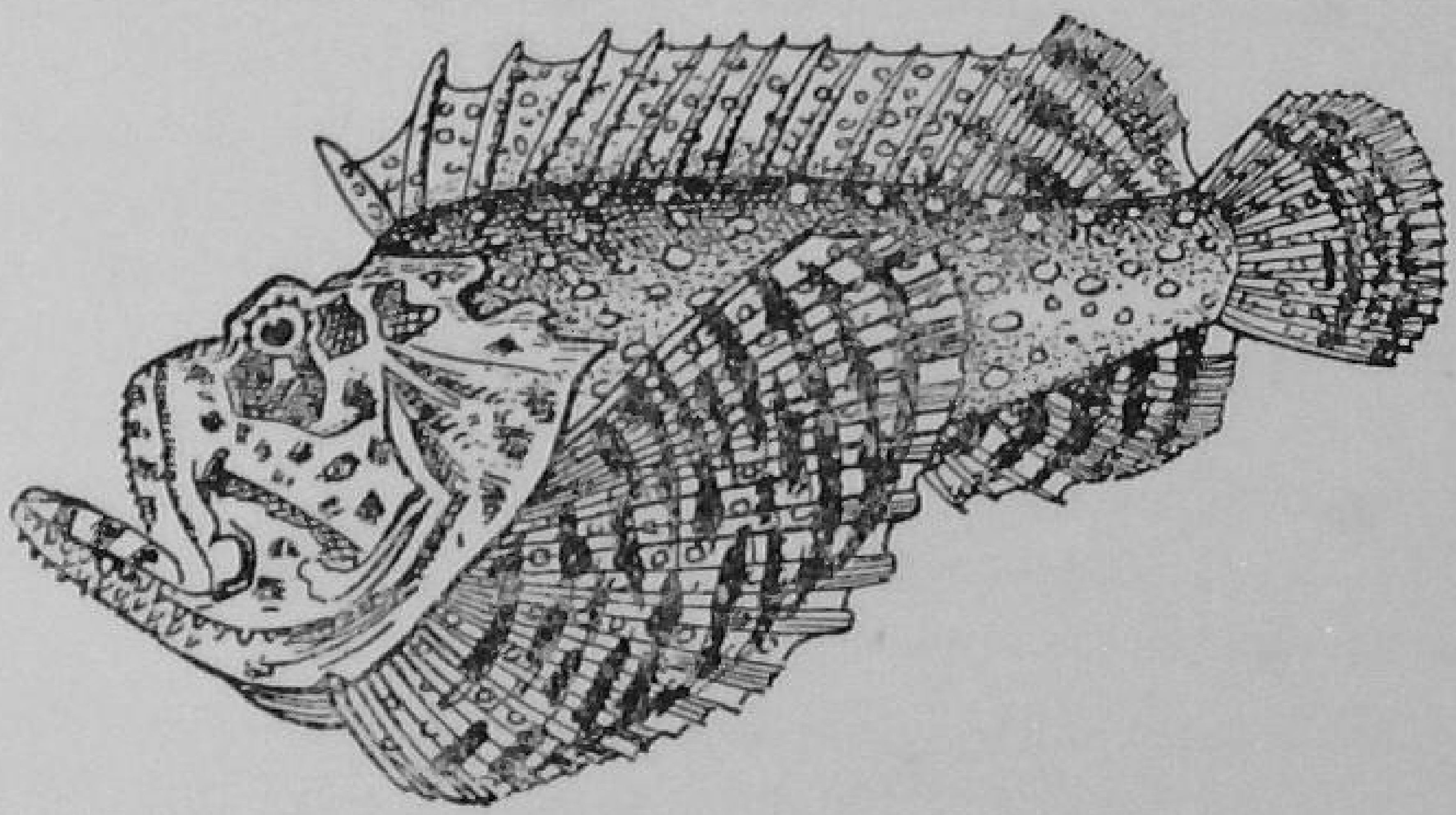

FIG. 25.—The Gofu. Poisonous fish found in the Indian Ocean.

anyone who tries to get hold of it. The two facts are quite definitely different, and they show the murry, of all fishes, as a poisonous animal in a more complete and precise sense.

But this special quality, this distinction, is more apparent than real. The toxic products, capable of exhibiting poisonous qualities, which come from the mouth, are not the only ones which the organism is able to give forth. There are others, engendered in other parts. The blood, gathering them to itself, holds them dissolved in its serum. The latter, in the murry, possesses toxic properties. If it is extracted and used in inoculation, effects are observed com-

parable to those produced by a bite from the creature's mouth. The poisonous function, while it is more clearly displayed in the action of a definite organ, belongs to the creature's substance: it has a general character, which a more accessible and easily realized localization should not disguise. The teeth in their own way, and so far as they are capable of so doing, only make use of a property of more extensive type.

Moreover, people have long known that one cannot handle with impunity the bleeding slices of a freshly cut up eel. If there are scratches or broken skin on the hands, these will become more painful if the blood

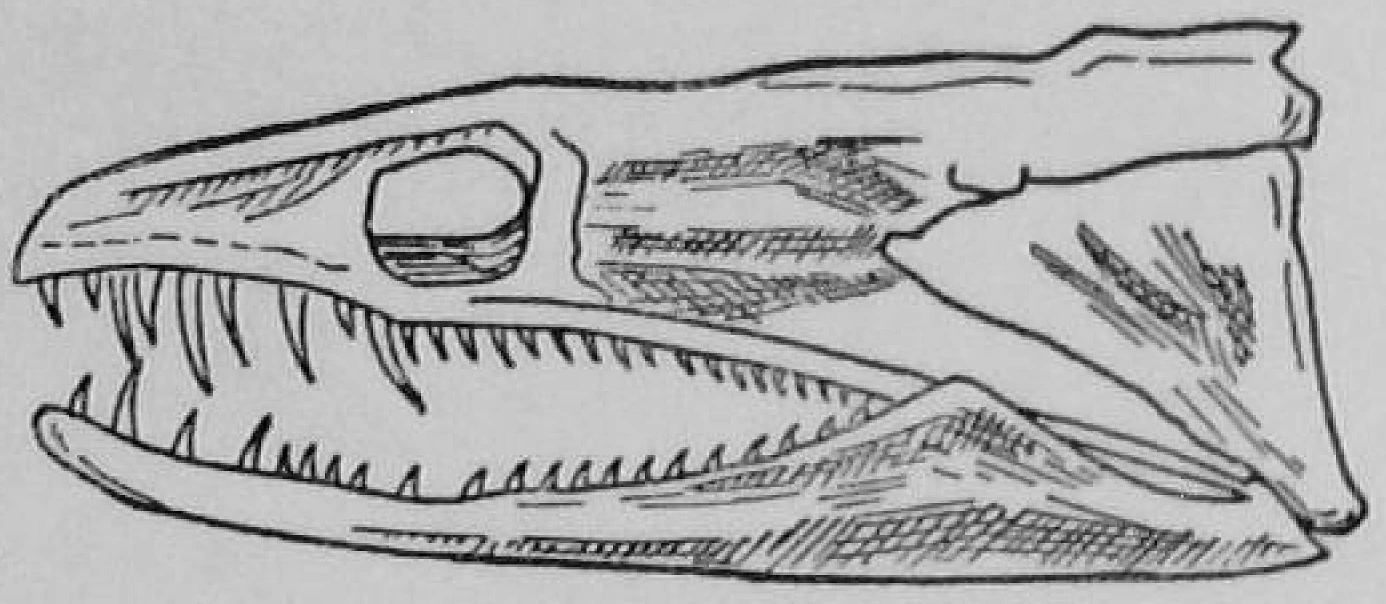

FIG. 26.—Skull of a Murry, showing the large upper teeth which act as poisonous fangs.

touches them, and take longer to heal, as though the contact had poisoned them. This, indeed, it actually does. The eels belong to the murry's group; they have the same essential conformation and the main characteristics of its organization; they share its capacity to produce toxins. In them, too, the blood serum contains substances like poisons. This capacity remains confined in the eel's body and only displays itself when there is an unexpected contact between its blood and a wound already made. In Nature, in the normal course of existence, nothing of the sort would happen. But the capacity exists, secret and hidden. In this group of fishes, before it can become evident to us as an episode of normal life,

as a function that is actually realized, we must have the special case of the murry, more effectively armed than the others, equipped with larger teeth, and so capable of making use of a power which all possess to a greater or less degree.

This poisonous quality in the animals which it characterizes creates a most alarming impression because of its violence. On land, the sting of a wasp, the bite of a viper, surprise by their suddenness, by the intensity of their effects. We are astounded by the vigorous, tragic action of those few tiny drops of liquid which are introduced into a wound. We

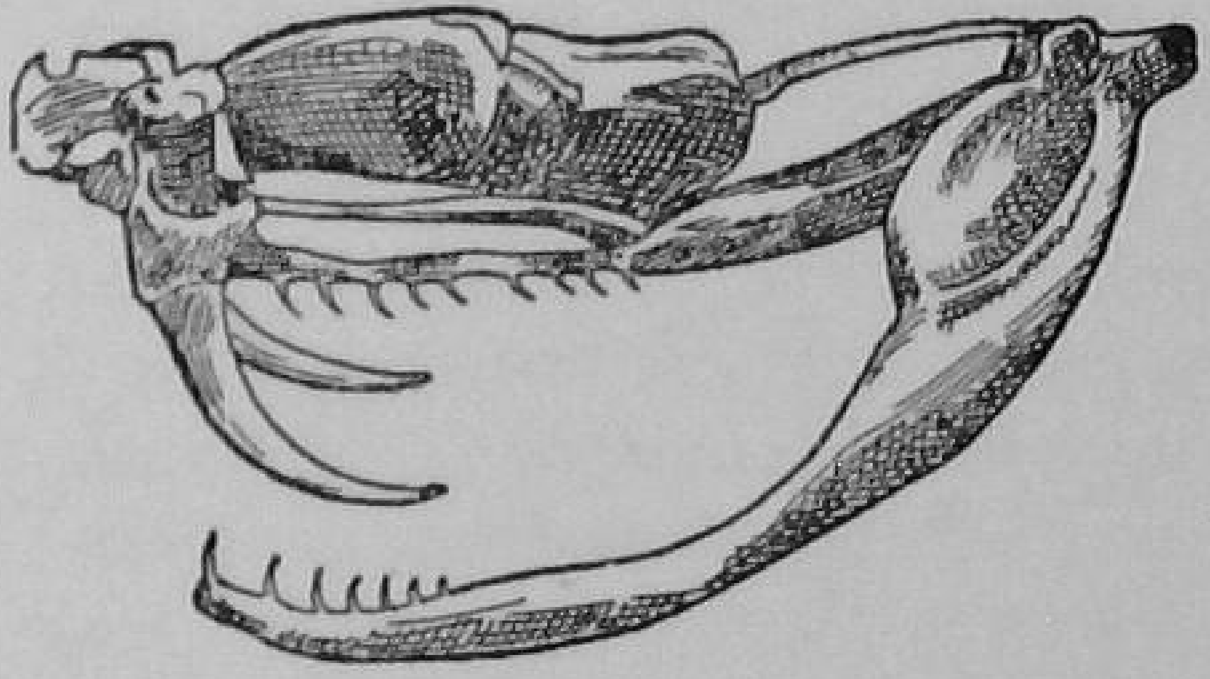

FIG. 27.—Skull of a Pit Viper, a poisonous snake, showing the large upper teeth which act as poisonous fangs.

give special attention to the organ which causes the wound, the sting or the tooth; we are on our guard against it, and rightly so. We think less of the poison itself and of the organs in which it is prepared. Yet theirs is the principal part, and biology spends its efforts upon the study of them. It discovers the same principles everywhere. If, at one and the same time, the poisonous creature possesses the toxic quality and the means of inoculation, this property is not restricted to the organ; it exists elsewhere, but not in use, since the inoculating organ is lacking.

We often see things in their relation to ourselves alone, and we consider Nature through eyes which have, so to speak, preconceived ideas, according to

the benefits we secure from it or the inconveniences we suffer from it. We are apt to classify the creatures which normally surround us as useful or harmful, or neither one nor the other. Among those we call harmful, those which are venomous attract a good deal of our attention, and we try to find means to protect ourselves accordingly. We make of them a class apart, in which we assume that the gland which produces the poison, and the instrument which serves to introduce it, make up a structure, the two components of which are narrowly related. We consider, further, judging by the perfection which this mechanism sometimes displays, that it represents in its own way a condition clearly devised for the needs of attack or of active defence, and we are apt to see in this specialization the reason, the only reason in fact, for such an organization. But this is not at all the case. There is only agreement of a general function with the presence of an apparatus which is able to make use of it in a particular way. The tragic power of the poisonous creature is only a part in a greater power, a more complex and extended power.

The world of waters shows this better than the world in which we ourselves live. Poisonous animals are numerous in that world, and fishes are not the only ones. In the case of many, if not all, the power is never really used. Though, on land, its frequent use seems to indicate the idea of some functional relation, nothing of the sort in normal life is to be observed in the other. There the effective capacity is rarer than the possibility.

The rocky structure of the tank, of which the murry occupy the holes and hollows, is adorned, here and there, by sea-anemones, their columnar bodies attached by the base, and crowned with a coronet of supple and contractile tentacles. They, too, are poisonous animals, and their name "sea-nettles" expresses the fact very well. If I take one, pull it away from its

rock and rub it in my hands, I feel a stinging pain at once, and there appears on my skin a broad patch reddened by the inflammation that is setting in. The symptoms, which vary according to the individual, according to the tenderness of his skin, take a long time to abate. The poisoning capacity, possessed by this creature of such an elementary structure, so far down the scale in the classification of the animal kingdom, is something real, apparent, relatively important. But the actual poisoning mechanism differs from that of higher animals. Instead of consisting of relatively large organs, such as teeth or stings, confined to definite parts of the body, it is scattered about in tiny microscopic cells distributed over the surface of the whole body.

Each of these cells—and the animal contains thousands of them—consists of a vesicle filled with a liquid in which is a filament rolled in a spiral round itself, whence its scientific name *nematocyst*, which comes from the Greek and means "thread-cell". When I look at the parts which contain them under the microscope, on a fragment specially prepared, I see hosts of them, scattered about, all alike. Their liquid is a poison, their filament a sting intended to inject it by making a wound. If I touch the part containing them, the tiny walls of these vesicles break down and expel their contents, and the filament, suddenly unwound like a spring, jumps out after the fashion of a tiny catapult. Since it was my hand that caused the contact, these filaments, which end in a point, entered my skin, carried along with them little drops of the poisonous liquid, and the result was the rash from which I suffer. The apparatus is minute: the naked eye cannot see it, but the number of such mechanisms makes up for their tiny size.

Some of the sea-anemones are still better armed. They contain thread-cells, not only in the external portions of their bodies, but also in the internal parts,

in unfolding twists which can come out of the creature, if it is excited, through the mouth, or through the orifices with which its trunk is pierced. It is interesting to watch these creatures, when touched, first of all contract, then sink, and at the same time expel and spread around themselves the little spirals which jump out like rockets at a firework display. But when they are expelled, all is over; they cannot go back to their old position. They become detached from their

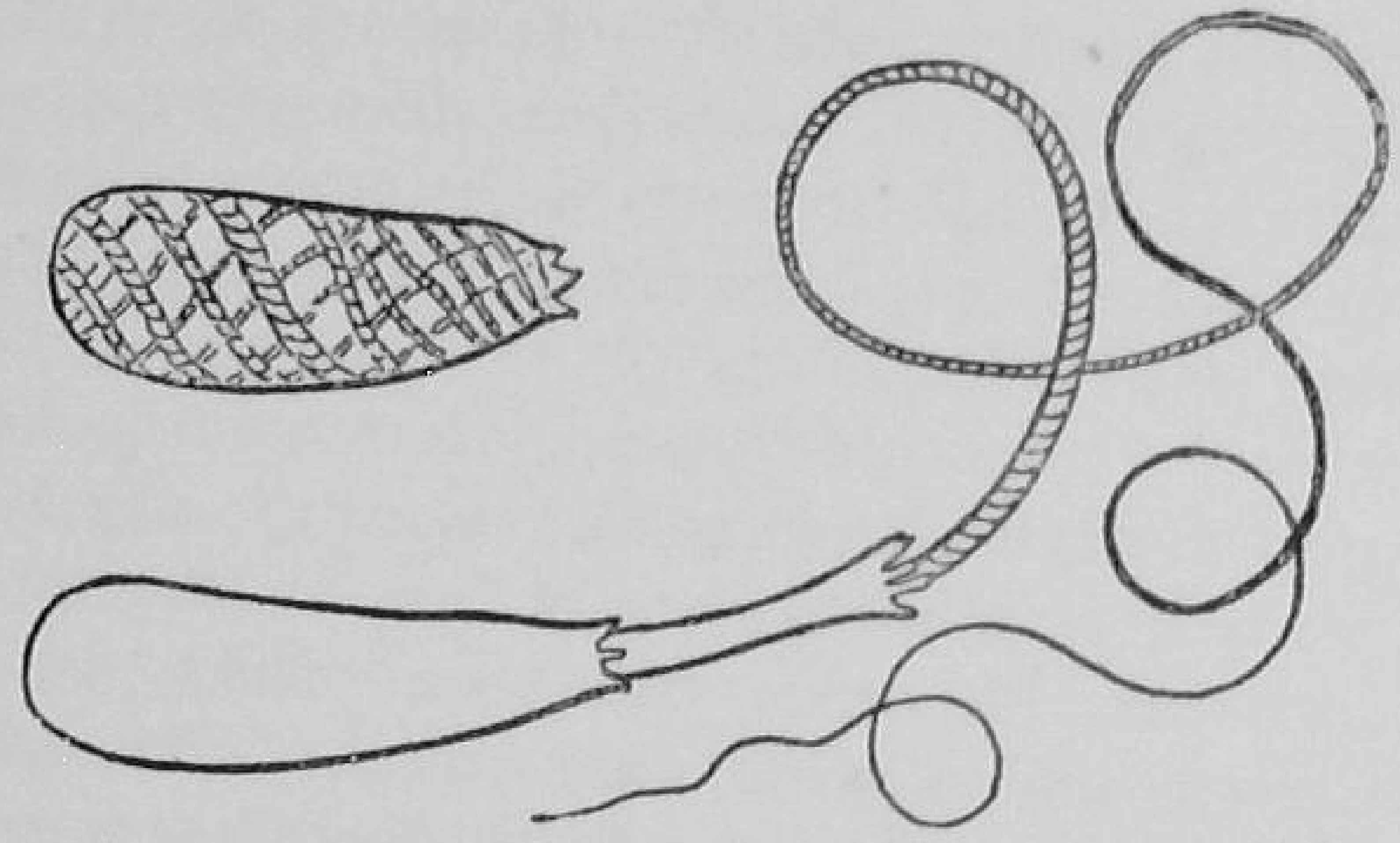

FIG. 28.—Thread-cell greatly enlarged. Above, the whole cell, with the filament rolled up inside. Below, the cell when it has put out the stinging filament.

owner, break off and decompose, like organs that have been cast aside, like excreta.

In the extraordinary, many-faceted world of the lower animals, the sea-anemones, in their capacity of venomous creatures, are not alone. The pretty jelly-fish, with body opaline in appearance, suspended in the water, have tiny thread-cells on their flexible tentacles which hang loosely in the water. Other floating creatures, collections of polyps making up the class of Siphonophores, also have tentacles of the same sort, but rather longer. This translucent population which fills the upper levels of the sea with a myriad individuals also has its poisonous creatures, invisible or difficult to see in spite of their size. At the bathing season, we suddenly

feel a sharp pain on the body; we touch, look at the wounded spot. Only the redness, the stinging sensation tell us what has happened. A jelly-fish has passed, touched us, stung us with its batteries. We did not see it, but it touched us and left its mark.

What are we to think about these different kinds of organization, which are found in so many different places, in such varying forms ? The case from which we started out, that of the murry, has developed to an unforeseen degree. By considering it together with similar cases, the first idea we formed has both changed and extended. Starting as a specialized and particular phenomenon, it has become a general phenomenon, which one feels has a connection with the elementary conditions, still more general, of living beings as a whole. The particular function becomes a single one of the modes of a complete system of action, on which it depends, whence it takes its origin, and in which it loses itself as it is accomplished. When we speak of poisonous animals, we bring to mind, more or less distinctly, the most categorical and best known example, the venomous snake. We are inclined to judge the others by its standard, or at least to make comparisons with it. In the viper we find a mechanism carried to the highest pitch of organic perfection, with a definitely localized gland in which the toxic liquid is produced, and a tooth provided with tubes running through it which take the poison straight to the bottom of the wound which it causes. Therefore, without being able to confirm the truth of this idea, we conclude that the organ is indeed made for the function it has to fulfil; that both organ and function agree in the most complete manner; and that the whole forms a dangerous weapon, expressly designed to serve both for attack and defence, and that it has no other purpose.

But the case of the murry compels us to be less categorical. Its bite, like that of a snake, is poisonous, but the area in which the poison is produced is diffused

instead of being localized, and the teeth have no tubes to facilitate the inoculation. Furthermore, instead of being concerned with the mouth alone, so that, as in the murry, there must be a bite for the damage to be done, the venomous quality is distributed all over the surface of the body, is exercised by means of organs on the surface—spines or stings—and only comes into operation in a passive way. Moreover, we find that these toxic substances which provide the venom with its painful properties are related to other substances of the same order, held in solution in the blood of a large number of animals which have no inoculatory organs, yet do possess a sort of secret, inner venomous property, which is not made manifest by anything external. So the poisonous creatures can no longer be put into a category by themselves: they are like the rest, and differ from them only by their capacity to make use of general properties in an additional, complementary manner, which is governed by the possibilities of their construction. When we consider animals still more simply organized, the jelly-fish and the sea-anemone, we are confirmed in this idea, since we find these same properties distributed over the fundamental elements of the tissues.

What, then, are these active substances which the body produces in infinitesimal quantities, yet which, despite the degree of their dilution, are so vigorous in action? Experimental medicine here works hand in hand with biology. The means of investigation at its disposal enable it to penetrate even further into the knowledge of things, for it defines them more clearly on the basis of the results made manifest in illness.

The maintenance of the living creature in its unitary simplicity has an astounding complexity. The tissues, working in the midst of the liquids with which they are bathed, modify them according to the needs of the function they have to perform. Their vital action, deep down within them, carries all of them along

in a series of continual transformations, in which the energy of metabolism and its reactions terminates in the continuous creation of substances which, possessing at least a temporary usefulness, reserve it for the organism in which they are formed, sometimes losing it or modifying it when exteriorisation takes place. Such is the case with the poisons.

So, the assimilation involved in maintenance brings about a succession of phases, produces substances in series which act one upon another as much by their peculiar composition as by their molecular texture. A degree of regulation is established which, making all these parts dependent one upon another, causes them all equally to work together to preserve life. To serve the individual as a defence against the external world is not the sole purpose of the toxic substance of the poisons: in the first instance, and principally, they serve itself in the interior nutritive exchanges of its individual life. It is, as it were, a derogation for them to employ themselves externally: their essential and primary use is within the organism.

The murry, waving about in its tank, has its true and complete appearance. Its evil-looking little head is not the only feature to be taken into consideration: the large strong supple body acquires the predominance which befits it. It is, indeed, always a venomous creature; but above all it is an equilibrated creature, in which everything is arranged to ensure existence. The harmonious winding to and fro in the water is a picture of the harmony established in it, in the interplay of its organic parts, established that it may live without too many difficulties. Its poisonous bite is only a side-line, an accident. The main consideration is contained in the work of the vital processes, a work that never ceases, carried on within it, in which the continuance of existence endeavours to preserve, and to defend against attack, what the life of construction, in all forms of living flesh, has succeeded in building up.

CHAPTER X

ELECTRIC FISH

I HAVE spoken somewhere of the old country fairs at which one used to see freaks and monsters of all sorts exhibited. There were not only calves with two heads, sheep with five legs, dog-faced men, and mermaids. There were torpedo-women. You went into their booths, and found a princess, a fairy, or an old witch, according to the dress she happened to be wearing that particular day. She would hold her hand out to you, or touch your shoulder with the tip of a metal wand, and you straightway felt the tingling of a slight electric shock. The woman was standing on a support electrified by a concealed battery, and contact with her produced the shock.

Not more than a few years ago, electricity was a fluid known only to the physicists and found only in their laboratories. The general public knew very little about it. Now it has developed into a form of energy of which the whole world makes use. The booths in which the torpedo-women appeared were dimly lighted by a few smoky flares. Those days are now over. In the fairs of today we find festoons of electric bulbs. Occasionally in our own homes, when repairing a short circuit, or changing a bulb, we feel a shock like that given us by the torpedo-woman. Everywhere about the countryside we see pylons supporting wires which carry electric energy to factory and cottage. The scanty fluid of former days has been transformed into a valuable and beneficent force, and it has been made available throughout the length and breadth of the land. Perhaps, when we think of its adaptability and the ease

with which it can be employed, we are apt to forget the formidable qualities it still possesses. We are only accidentally reminded of them when we read notices regarding the risks of electrocution. But it keeps those qualities, and sometimes they are revealed in tragic fashion. Electricity has been humanized, but it still remains the weapon of *Jupiter tonans*, the god of antiquity, who manifested himself in thunder and lightning.

There was good reason for the name "torpedo-women". We produce electricity by using the resources of inanimate nature, with the help of various kinds of apparatus, batteries, dynamos, waterfalls, but living nature has animals which can do as much, in and by themselves. For this purpose they are provided with specialized apparatus consisting of organs which give off electricity in the course of their normal activity. These creatures are not very numerous, but their very scarceness makes them the more interesting. They belong to all the groups of fishes. The commonest, and those which have been longest known, are the torpedoes, which form a particular family related to that of the skates and rays. From their name and properties has arisen the verbal assimilation which has passed into ordinary language and, by derogation, into that of ballistics.

When, knowing the powers with which it is invested, we look at a torpedo, we cannot help a feeling of some surprise, so little does its placid appearance indicate its capacity for giving off electricity. The fish is flat like a skate, but thicker and rounder. Its body—the head is fused with the trunk—has the form of a circular disk terminated by a short but relatively thick tail. Usually the creature lies flat and motionless on the bottom. It seldom moves, and then only for a short time. Its sleepy lethargic behaviour gives no indication of the secret power it possesses.

The torpedo is a sea fish. It lives on the muddy or

sandy bottom off the coast, and there it lies half buried. Skate, turbot and devil-fish live near it, all fish which are familiar to the fisherman. We shall not have any great difficulty in catching it. The seas of Europe know two main species, the marbled torpedo and the eyed torpedo. The former is more often found and is the larger; certain specimens may be nearly three feet long, if we include the tail. Its reddish-grey back, striped in shades of the same colour, is responsible for its name "marmoratus" or "marbled". The latter is practically confined to the Mediterranean, and is more richly coloured and better looking. It has several large round eye-like patches, usually five in number, of light blue with a double circle of black and yellow round them, upon a red-brick shading into yellow ground, finely touched with white which makes them stand out more clearly. This adornment of the upper surface, which may not unreasonably be compared to that of a peacock's tail, is in contrast with the lower surface, which is white with a delicate shade of rose enhancing its satin-like lustre. The openings of the gill slits stand out darkly on this background, and so does the mouth connected at its angles to two deep nostrils. The two eyes, each with an air-hole near it, are conspicuous on the upper side, near the front of the disk.

Fishermen give them a number of nicknames, all of which have reference to the effect felt when grasping them. This is like a series of rapid and successive electric shocks, which begin as soon as the fish is touched and cease the moment the hand is withdrawn. The torpedoes are often alive when taken out of the net and go on living for a fairly long time. They can produce a discharge which, though it is never quite powerful enough to be dangerous, is definitely disagreeable. It is in proportion to the size of the animal. In order to experience it, it is necessary to grip the creature with the whole hand, passing the palm under the belly and pressing the thumb on its back. So the circuit, which

goes from one to the other, is closed and, if the discharge is sufficiently intense, it can be felt in the hand and arm, even in the shoulder and side.

A power so strange as this could not fail to give rise to a certain amount of research. In marine biological institutions, the torpedo has become a laboratory case on which considerable study has been, and still continues to be, expended. It is also a favourite exhibit in aquariums, because it is easily kept in tanks. So there is no difficulty in getting hold of one to study if we wish to find out what this strange property is, where it resides, and whence it comes.

There are two organs concerned in producing the electricity which the creature puts forth. They are of similar size, large and symmetrical, and take up the greater part of the two sides of the body. As soon as we have removed the skin in our dissection of the fish, we find them. They are whitish in colour, and each is composed of a mass of little prism-shaped columns lying side by side. These prisms are hexagonal and the appearance of the whole is that of a honeycomb on a small scale. In both cases, mutual compression is responsible for the hexagonal contour, which is the shape best fitted for economy of space.

If we isolate several of these little columns to find out how they act and how they are made, we discover that they are all alike. They are almost the same size and all reach from the upper to the lower surface of the body. All the prisms have the same structure. Each is made up of very thin disks, superimposed like stacked-up squares, and separated by intervals of a less coherent tissue. This immediately makes us think of a comparison. Each prism is like a miniature voltaic cell with its successive disks. The whole organ then appears as the equivalent of a group of disk-shaped cells, the elements of which make up for their tiny size by their prodigious quantity. They vary in number according to the size of the fish, but there are several tens of thou-

sands of them. A torpedo of average size has from 400 to 500 prisms, each with 300 to 400 disks, that is 120,000 to 200,000 elements. In this living electric battery, so original in its complexity, are the terminations of large nerves which come from the brain and

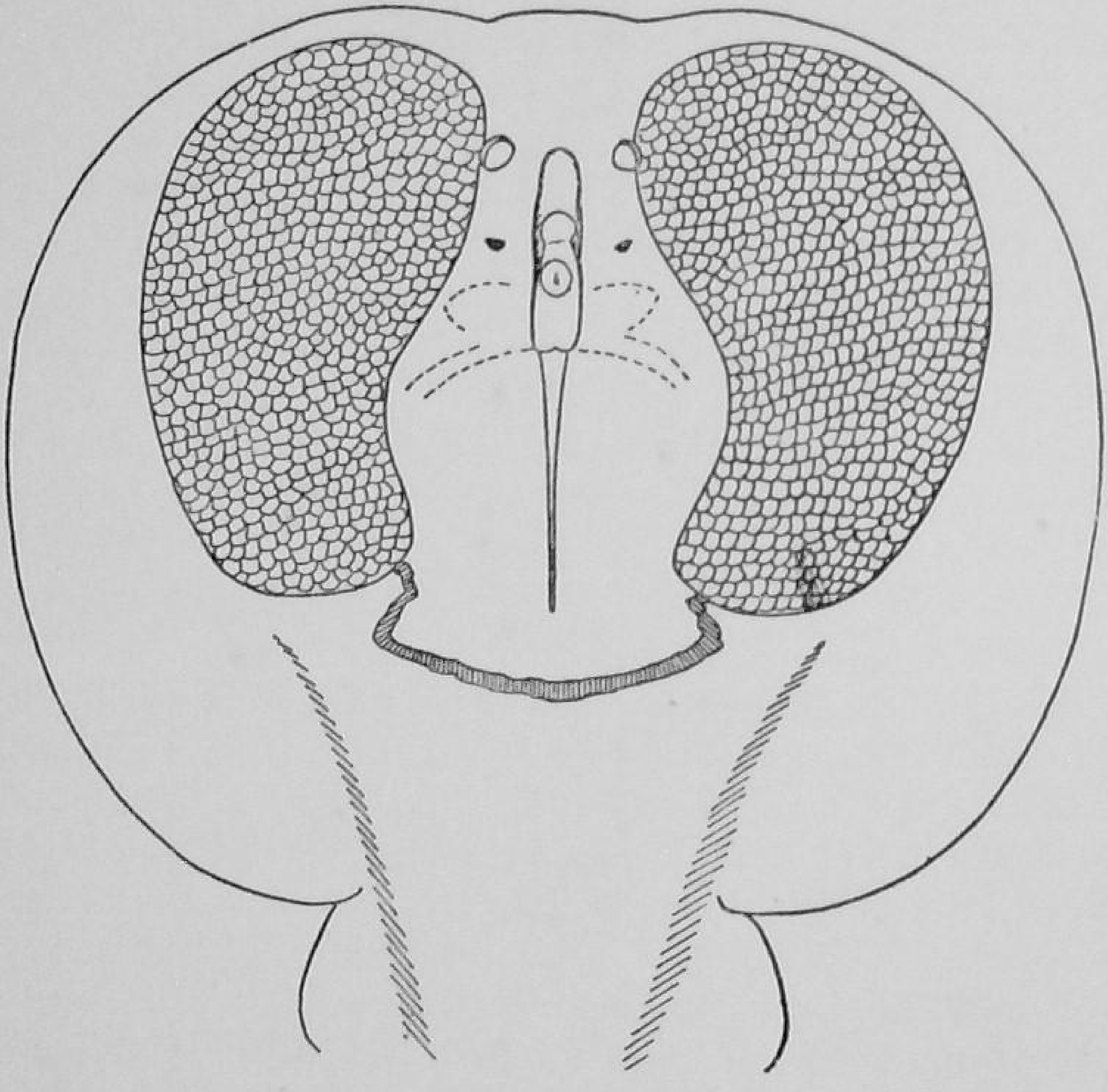

Fig. 29.—The discoid body of a Torpedo, dissected so as to show the two electric organs of areolar appearance.

bring their branches to all parts of the apparatus. This nervous inflow acts as a control, and when the discharge of electricity takes place, the current is directed outwards from the back, which is positive in polarity, to the under side of the body, which is negative.

Our first impulse on becoming acquainted with a structure and properties of this sort is to assume that the animal makes use of them for attack or defence.

There is every reason to think that it does. The living battery is composed of elements that are certainly small and weak, but it makes up for this by having an immense number of them, and, added together, these minute discharges produce a high voltage, the effects of which are appreciable. The intense effects upon a human being give us an idea of what can happen in the water, when they are brought to bear upon the small creatures there.

But actually, when we observe torpedoes in a tank, we find nothing of this. They lie flat and motionless upon the bottom, or upright against the glass. Near them, around them, even passing over and touching them, we see all sorts of fish coming and going in every direction without appearing in the least afraid of their dangerous neighbours. There is no discharge of electricity. Nothing happens. The torpedo remains inert, and the tank-dwellers go about their business in perfect safety.

It may be thought that this indifference comes from the state of captivity and the lessening of vital activity which results from it, and that in natural conditions the torpedoes are less placid and, as their structure would lead us to expect, kill their victims with the electric shock and then devour them. But this, again, is not in accordance with the facts. Their ordinary behaviour, their mouths fitted with small pointed teeth, rather incline us to assume that, in securing food, they act like the skate. They snap up on the bottom the animals upon which they feed, and need no electric shock to strike down their prey.

Occasionally, perhaps, the organ is useful for defence, for escaping the attack of a more powerful enemy, but there is no evidence that this rôle is effective and regularly used in the normal course of existence.

The skate have an apparatus exactly similar, but much smaller. It is differently situated, being not in the body but in the base of the tail. They, and the

torpedoes, are the only sea fishes provided with such an equipment. Fresh water, on the other hand, has three kinds of electric fish, the mormyros, the electric catfish, and the electric eel, which all live in warm subtropical regions, the first two in Africa, the last in Central and Southern America.

The Mormyros, distinguishable by their long snouts, drawn out like a tube, are little better equipped than the skate. They have only a small electric organ. Their body is not flat but of the usual shape, and has the electric organ at the hinder end of the trunk near the place where the caudal fin is attached. The catfish show a definite improvement upon this. They are typical

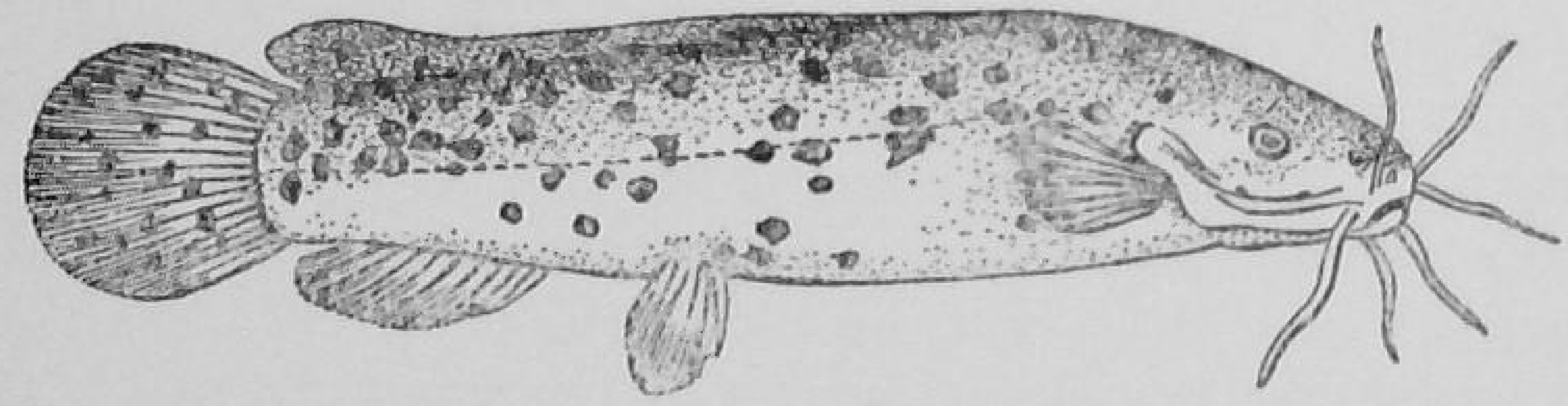

FIG. 30.—Electric Catfish, which may be two feet in length.

of their family, with long plumpish bodies, bearing long flexible barbs projecting round the mouth. They may be from 20 to 30 inches in length. Their electrical apparatus is not massed together as in the torpedo, but spread almost round the whole of the body like a cloak. Consequently, although it is not very thick, its extension gives it a capacity greater than that of the torpedo, its total voltage being greater and the discharge more intense and startling.

Of all the electric fishes, the best equipped are certainly the electric eels. In the natural state they live in the vast basin of the Amazon, especially its lower and middle reaches. There they are common, living by choice in calm, almost stagnant, waters, burying themselves in the muddy bottom. They look like enormous eels, though zoologically they are not akin to them.

They may be as much as six feet long. Their electrical capacity, and the way in which they use it, are far beyond those of any other fish. They, like the torpedo, have two voluminous organs symmetrical and of the same size, but these organs have a different situation in the body, and their size is proportionately greater. Each consists of a thick mass, situated in the sides but continuing under the belly and reaching from the fore part of the trunk to near the tail. They are made up as usual of little prismatic columns placed side by side and subdivided into disks, but the columns are divided horizontally and not vertically. So, compared with the torpedo, we find a difference in the direction and position of the batteries and consequently a difference in polarity. In the torpedo, the positive pole is above, the negative below. In the electric eel, the positive pole is in front and the negative pole behind.

Not long ago, I owned three living electric eels which had come from Guiana, and kept them several weeks in a tank, unfortunately not long enough for all the observations I hoped to make. Usually they lay upon the bottom, getting up at intervals to swim about the tank, then sinking again to the bottom. They then showed, as they moved easily about, how little resemblance they really have to the eels. Certainly they are long and cylindrical and swim with a flexible and serpentine movement, and they are brownish-grey in colour, but in every other respect they differ. The head is broader and larger, flat on the top, and shaded underneath with a fiery red hue which continues under the neck and the body. All along the lower side of the tail runs a fringe-like anal fin, which aids in swimming. Their method of swimming is as rare as it is curious, for it is helped by the possession of this supple lower fin, broad and long at the same time, and this peculiar feature is seldom met with. According to the rhythm and direction of the movements, the fish goes forwards or backwards. When we watch its evolutions, we enjoy

the uncommon sight of a fish which can swim in two opposite directions at will, full steam ahead or full steam astern, using this fin alone, without bending or twisting its body, or turning round.

When we look at it in this way, the electric eel, like the torpedo, gives the impression of a calm, placid animal which readily becomes lethargic and only occasionally rouses itself. In its native waters it probably stays motionless, its body buried in the mud. But the situation alters when a fish that looks a likely prey comes within reach, or when some large animal tramples the

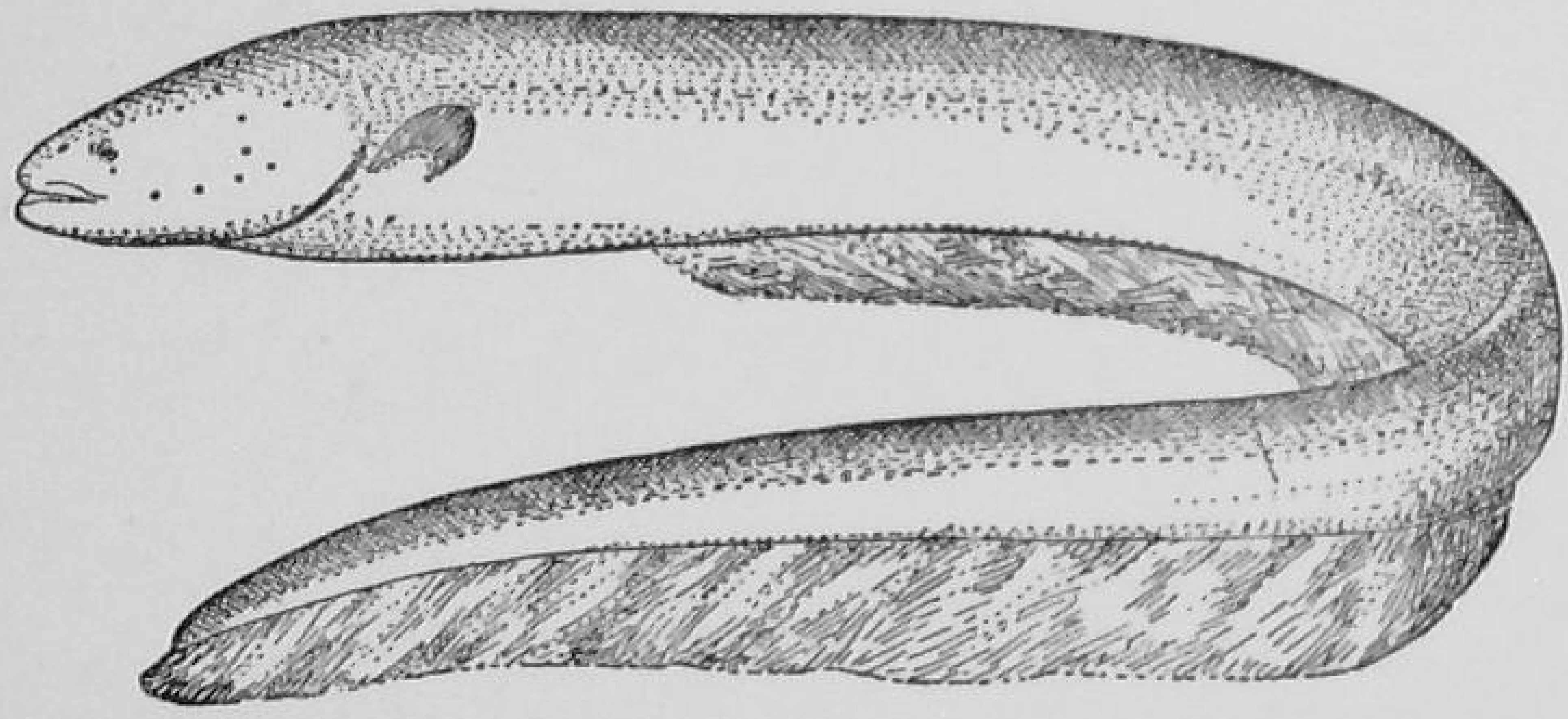

FIG. 31.—Electric Eel. May be six feet long.

mud where it has taken shelter. Its inertia suddenly ceases; it darts forth, swiftly and with agility; it discharges its batteries and strikes down the intruder. Not at all like the torpedo.

Those I kept were fed once a week on little live roach which were thrown into their tank. In the twinkling of an eye, the appearance of the tank was utterly changed. Previously it had been peaceful, with the electric eels reposing tranquilly upon the bottom. Suddenly it became the scene of an intense agitation. As the little fish went down and were scattered in the water, the eels, suddenly becoming active, dashed upon the offered victims, struck them with a flash, and gobbled them

down at one gulp. They were everywhere, darting up and down, from one side of the tank to the other, stirring up the water in every direction. The little fish, thus hunted down, tried to escape, but they were soon caught by the electric discharge, killed or at least paralysed by it, and, turning belly upwards, gradually sank. The eels swallowed them whole, then dashed after others which met the same fate. This extraordinarily sensational chase, in which the pursuer killed the prey by electrical discharge, lasted for several minutes without stopping. Then the eels, gorged and replete, slackened their pursuit. They were growing weary and their electric power was becoming exhausted. They lay down on the bottom again to digest their food in peace, their stomachs swollen out by the copious meal.

When the agitation was at its height, a strange phenomenon might be observed. Now and again the eels gave up their chase for a moment, stopped moving, and sent out large bubbles of gas from their mouths, which rose through the water and burst on the surface. After this they began their chase again. These expulsions of gas took place several times during the electric discharge. In the state of rest, on the other hand, nothing of the sort took place, or it was only on a very small scale.

We find an explanation of these astonishing actions when we compare them with a voltaic cell. The eel, with its two interior batteries which produce electricity under the voluntary action of the nervous system, becomes an electrified body with a high potential. This body, having two poles, situated at the two extremities, the electricity is irradiated all round them, as in the well-known phenomenon of the magnetic spectre; they can be shown in an identical graph. The lines of force of the discharges radiate round the positive pole, which is in front; some are lost, while others go to rejoin the negative pole behind. This body, producing

electricity at a high voltage, is surrounded by water, which is a good conductor, and is thus charged with electricity at high tension. The fish which come within its sphere of influence are electrocuted even though they may not touch the eel, and indeed may be some distance away; the most powerful discharges emanating from the front, which is the positive pole. The movements and manœuvrings of the pursuing eel add to this effectiveness, sometimes bringing the head closer to the tail, and thus diminishing the distance between

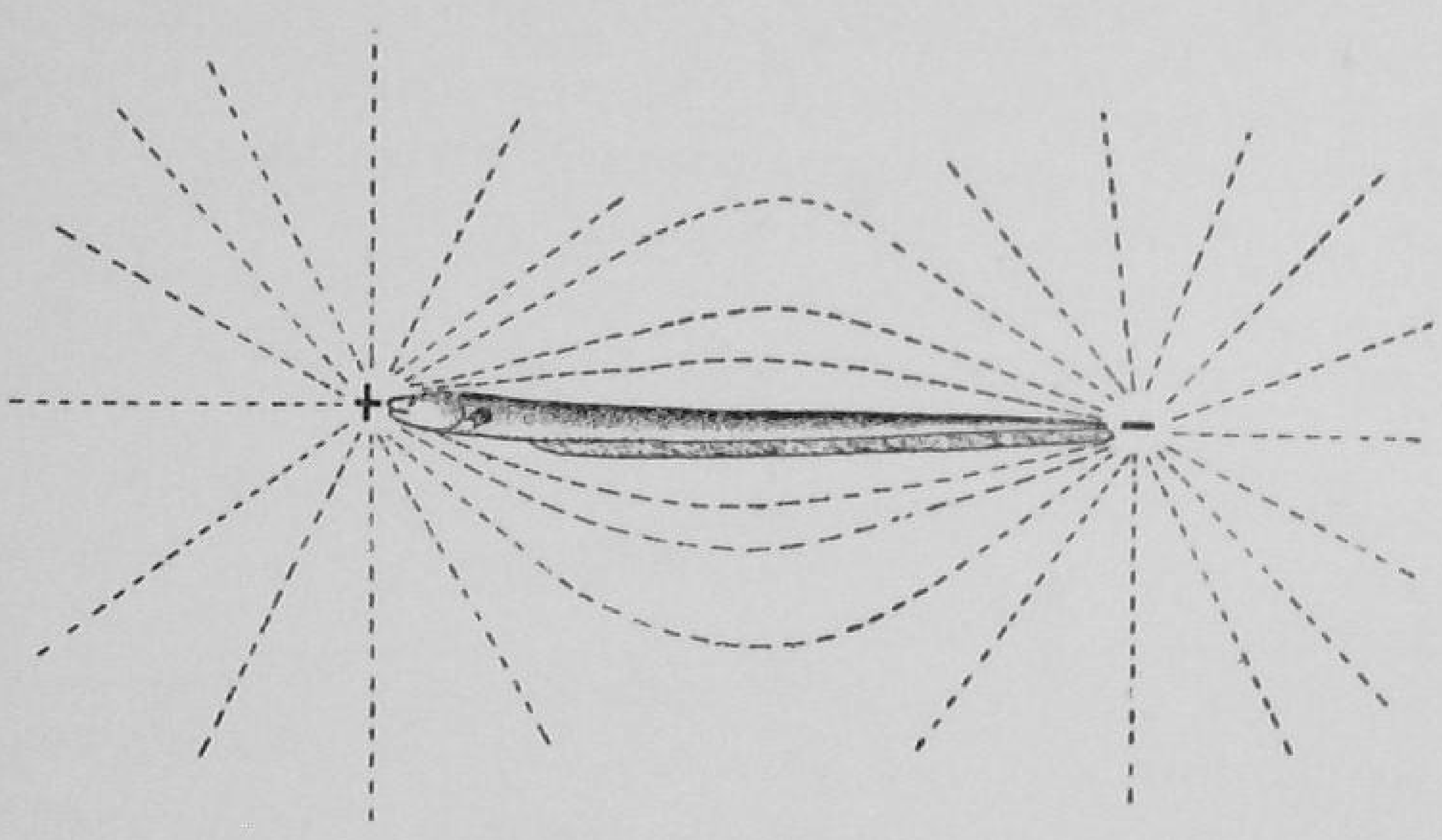

FIG. 32.—Lines of electric discharge in the Electric Eel.

the two poles, and making the discharge correspondingly stronger.

When batteries with metallic plates are in action, they give off bubbles of gas, oxygen and hydrogen, produced by the decomposition of the water which surrounds the plates. There is more hydrogen than might be expected because part of the oxygen settles upon the metal disks. The production of electrical energy in these batteries is one of the consequences of the chemical actions which go on in them, and one of these actions is the decomposition of the water. In the living battery the process is exactly the same, the plates here being

composed of organic tissue. The nervous system produces chemical action with identical results. The water in which the disks are bathed is decomposed in proportion to the production of electricity. Part of the oxygen remains, absorbed by the tissues for purposes of respiration; the surplus, with the hydrogen, passes by diffusion into the digestive tube, and is expelled from it as these bubbles which are seen to leave the eel's mouth when it is hunting down its prey.

A resemblance of this sort, extending even to details, is in itself remarkable. If we wished to prove the identity of the vital mechanism with that of the physical mechanism, with the production of energy in both cases, we could not find a better or more complete example. Organic nature, far from being in contrast with inorganic nature, behaves in the same way in its processes. It does not matter that the movement which gives rise to these processes is of a different nature, higher and more complex; the same quality of impulse is none the less there.

What then are these extraordinary organs, these living batteries which, in all the world of organic beings, are found only in fishes, in which they produce such curious effects? Comparative anatomy has an answer ready. They are modified muscles, whose business it is to produce electrical energy instead of the accustomed mechanical energy.

They take the place of normal voluntary muscular tissue. They have the fundamental structure of that tissue. The muscles, or most of them at least, consist of bundles of parallel fibres placed side by side, showing transverse striation under the microscope. Hence the name "striated muscles" which is given to them. Similarly, the electrical organs are actually an assemblage of little parallel columns whose substance is cut up into disks set one upon another. It is not so originally. In the embryo of the torpedo, the rudi-

ment of these electrical organs is similar to that of ordinary muscles, and it is only during development that they come to differ. The primitive fibres thicken and change until they take the form of little prismatic columns, instead of remaining similar to the fibres of the striated muscles.

This likeness of structure applies equally to their action. The normal muscle acts when it is stimulated by the nervous impulse from the centres, the brain and the spinal cord. Before it receives that stimulation it is inert, afterwards it contracts. This contraction is not continuous but comes about in a series of successive, rapid shocks which run one into the other. In the same way the electric organ, innervated by large nerves from the centres, receives from them the influx which sets it in action. Then it produces electricity, emitting it at short intervals, in successive discharges which produce the shock. This electrical discharge is the strict equivalent of muscular contraction. The organ produces electricity as the muscle produces movement.

If we go further into the study of this remarkable likeness, we find out how it is brought about. The electrogenic property of these organs, in spite of its apparent precision and completeness, is not peculiar to them. It is found elsewhere, notably in the true muscles themselves, but it is less powerful and less apparent because it is hidden beneath other and more important functions. All living tissues, when they are in action, produce electricity, not very much, but in an appreciable degree. It is a consequence of the chemical changes which take place in them. Contracting muscles are more active in this respect. Not only does their action appear in the production of mechanical energy, but also in that of a relatively considerable quantity of electrical energy. The specialized organs of torpedoes, electric eels and the like, the organic batteries which these fishes have in their bodies, only accentuate a condition which is present to begin with. The mechanical power is

less important in them, and the electric power more so. They are electrogenic muscles, and that is all.

The vital process here exhibited deserves to be considered more closely. A circumstance so astonishing, so different from what we see elsewhere, stands out and, since we can the better appreciate it, it makes all the rest more intelligible. In short, this process manifests itself in two kinds of production, material substances and energy. As regards material substances, some remain and become part of the constitution of living matter, others are expelled as excretions. The energy has its origin in the chemical energy expended within the material texture, and expresses itself in movement, the formation of heat, and in electricity. These kinds of vital movement, these manifestations of the energy put forth by life in action are, in their own field, equivalent in part to the substances excreted. They are thrown out as excretions of energy; produced by the living creature, they first serve its purposes and then their surplus goes out to the environment and is there freed. In Nature there are only differences of situation and quantity; the fundamental quality remains the same everywhere.

If then, these electric organs, in spite of their strangeness, come within the scope of a general rule from which they do not depart, their peculiar rarity gives them a special quality of their own which, in its turn, merits close examination. They exist only in fishes. Again, they are found only occasionally and without any relation to the affinities of groups. In every other detail of their structure the eels are very far removed from the torpedoes, and the electric catfish from the skate. When these organs do exist, they are situated in different parts of the organism. There is indeed a sort of gradation in their capacity, which is moderate in the skate and the mormyros, more considerable in the torpedo, greater again in the electric catfish, and at its greatest in the electric eel. To put them thus into

series is a convenience for the mind, which takes into account only the degrees of this special capacity. There is actually no such relation in Nature.

The conclusion at which we arrive is that we are confronted with distinct and concrete cases, identical as regards structure and function, different as regards powers and distribution, with the added circumstance that they are found only in fishes. We have answered the question " How? " but can we answer the question "Why ? " At what door must we knock to gain some light upon their origin, the cause or causes which have brought them into being in the living world? What influence has been exercised over the muscles which act mechanically, to convert them into electric batteries? In short, whence does all this come?

The answers are plain. There can be no question of formation or progress by usage. There is too much of a jump from a normal muscle to even a rudimentary electric organ, and the distribution is not wide enough. Nor is their presence in the fishes that possess them due to affinity. Their occurrence is an example of a condition which, though potentially it can exist anywhere, is realized and found only in a few creatures. Doubtless, by reason of their dual electrical and mechanical power, all striated muscles possess the latent capacity to become electrogenic. But only a few of them have succeeded in realizing this.

Life, as it continually progresses up the scale, is devoted to two actions which are both simultaneous and mutually dependent. One, in the matter which it animates, unceasingly creates possibilities of structure, tissues, organs, and individuals. The other brings these possibilities into touch with environment, which provides the substance and energy which permit some to realize themselves and help towards their support, while holding up others and preventing them from getting any further, simply by refusing to support

them. We consider these results and see in what their essential origin resides, included in that activity peculiar to living matter by which we distinguish it from inanimate matter. We perceive that the living world, in its construction, in its division into individuals, is a reflection of this active force. That is enough. If the actual processes in their infinite detail sometimes escape us, we gain an idea of the law that controls them, and we learn how their course is governed.

CHAPTER XI

THE WHITEFISH OF THE LAKE OF GENEVA

From time to time we see things which have the power to move us more than any others. The end of a really fine day is one of them. The last few moments of such a day, as the sun goes down and twilight falls, are among the most fascinating and tenderly delightful. The harshness, the crudity of noon, are softened. The morning mists have passed away. The shadows and the lights come together; there is less contrast, and yet we get all their values. The atmosphere seems more equable, bathing everything, surrounding everything, bringing everything together with a delicate touch. The surfaces of ponds, lakes, and sea sparkle somehow more gently.

Sunset on the Lake of Geneva, after a fine summer's day, is one of the most glorious and affecting sights this earth can offer. The horizon, far enough away to leave an impression of vast space, yet near enough to give the eye a resting point without compelling it to grope in vague distances, presents us with a superb frame, in which the lofty, extensive barrier of the Jura, so dark blue that it contrasts vividly with the tenderer blue of the heavens, gives us, as it were, a measure of comparison. The sun, drawing nearer and nearer to it, lights up the delicate clouds which crown its summits; casting upon it hues of purple and gold; ever changing and always brilliant. They are mirrored in the calm waters, stretched out without a ripple, like a vast motionless and shimmering carpet. By degrees these glories fade. Dusk gains upon them, little by little, slowly, without shock or violence, but

with a serene majesty. And the starry night takes possession as assured sovereign of its empire, marking the quiet interregnum before dawn returns again. A series of tableaux of incomparable sweetness, which speak directly to the soul and move it as scene follows scene, awakening feelings of purest calm, of completest happiness.

Now this is only an appearance, a lie, a disguise beneath which is hidden a fearsome reality. Under that sparkling enticing surface, that picture of peace and serenity, there is in the deep water a continual struggle, a duel to the death. The search for food, the destruction of some for the maintenance of others, the never-ending sacrifice of the weak and the lasting triumph of the strong, are the guiding principle itself. They set the note of all that goes on.

As night falls, the fishermen go and spread their nets in the open waters of the lake. These nets are great, mail-like sheets, of considerable extent, and the fishermen suspend them in the water at different depths, so setting up a series of vertical barriers. During the night, when no light finds its way into the water, the fish, moving in all directions after their prey, do not perceive the traps thus set for them and, in the darkness, carried away by their impetuosity, strike their heads against the meshes, and so are captured. In the morning, the fishermen come out in their boats, pull in the nets loaded with the fish thus caught, take them on board, disentangle their catch, and return to shore.

During the summer, their catch usually consists of whitefish, char, and trout, excellent species, justly considered among the most delicate. Their exquisite flesh has a well-deserved reputation. In the baskets in which they are set out they delight one who beholds them by their fine shape and glorious colours. Later, they will charm the most delicate palate. They belong to the Salmon family, of which the salmon is the type, and they are distinguished by the soft isolated

little fin, known as the "second adipose dorsal", on the back, near the tail, behind the first and true dorsal supported by strong rays.

The trout, with patches of black on the sides and back; the char, of lighter hue and with more delicate scales, contrast with the whitefish. A powerful head, a large mouth cleft to the eyes, give them a greedy look, which the whitefish have not. The latter have a smaller snout, a narrower mouth, and smaller teeth, and are pale silvery in hue. Their scientific name is *Coregonus Schinzii fera*. In the family to which they and the trout belong, they form part of the section of whitefish which dwell in lake waters.

We eat their flesh, and it serves for our nourishment. They, in their native waters, have been obliged to nourish themselves in the same way, to form the flesh of their bodies by eating the flesh of other creatures which live in the same lake. They must find in it the prey they need. Their existence, which we turn to our own advantage, is determined by that of the creatures upon which they feed. Our nourishment depends on theirs. So, beginning with our own needs, we discover a cycle of nutrition which connects us with the animals hunted by the trout and the whitefish, and in this respect, makes us one with them, though they live their lives far away from us.

What are the creatures which are so useful to us, and how do they live? We find our answer in the fisherman's net. All I need to do is to clean the fish when the nets are pulled in, and examine the contents of their stomachs before the process of digestion has gone too far. So I discover what they have been eating and the nature of the creatures upon which they feed. In the trout and the char with the broadly cleft mouth I generally find traces, heads, vertebræ, and other bones, which have belonged to different kinds of fish, often fairly big fish, caught in the open waters. On the other hand, in the stomach of the

whitefish with the narrow mouth, I only notice a greyish hash, of which the naked eye cannot make head or tail. But if I take a powerful lens, this hash turns out to be made up of the shells and claws of tiny crustacea, which have remained after the digestion of the flesh they clothed because of their calcareous nature and their greater hardness. These whitefish, which are as great hunters as the trout but cannot, like them, attack powerful prey because their mouths are too small, content themselves with smaller victims, especially the tiny crustacea whose remains are found in their stomachs. They snap them up in the water, swallow them by dozens, by hundreds: their quantity makes up for their tiny size, and there are enough of them and to spare.

The various fishes upon which the flesh-eating trout and char customarily feed also devour these little animals; they feed their own flesh on theirs; and, indirectly, through them, the trout too find themselves dependent upon these minute crustacea. Consequently, the latter have a supreme importance in the alimentary cycle. Almost the whole responsibility for the nourishing of the more powerful creatures which pursue and exploit them rests upon them. The whitefish consume them directly; the trout and char use them through the intermediary of fish which have fed upon them, and we ourselves, at the top of the scale, reach them through both means. Consequently, they must have a truly surprising faculty for reproduction, and a wonderful capacity for adapting themselves, if at the same time they are to maintain themselves and make up for the destruction that goes on all the time. They are the born prey of creatures stronger than themselves, victims chosen in advance for a sacrifice they can never escape, but, none the less, they must survive to some extent in order that the balance may be preserved even if individuals suffer.

We find in the stomachs of whitefish fragments

which suffice for a superficial determination but are not sufficient to complete the picture. This we can obtain by catching these little animals directly, whole and intact, in the water where the fishes feed upon them. We know how to go about this—I have already indicated the method at the beginning of this book — we use a plankton net.

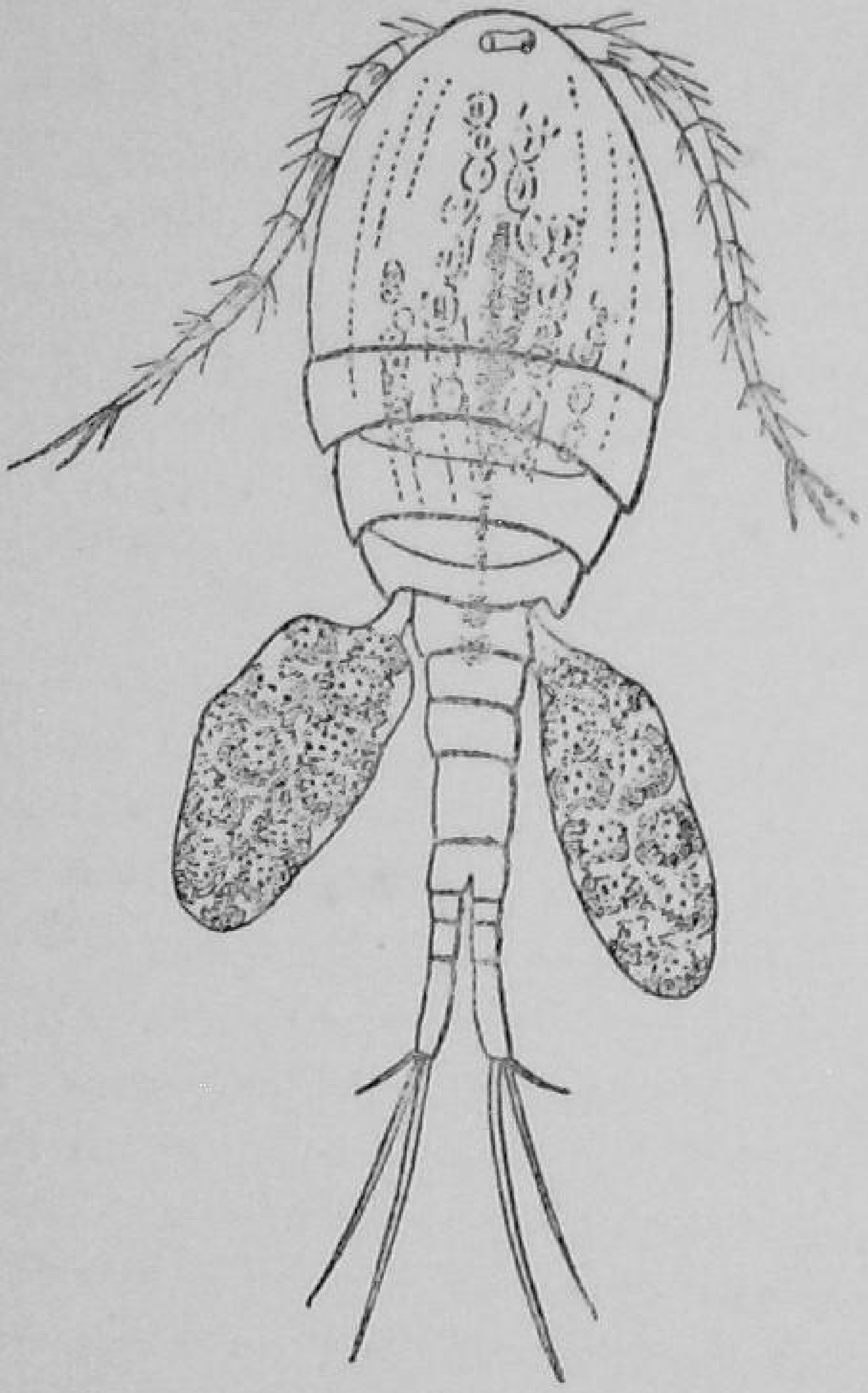

FIG. 33.—Cyclops (genus *Cyclops*), planktonic crustacean of the order Copepoda. There are many species, the largest of which are hardly more than 2 to 3 millimetres in length.

From my boat I draw this apparatus for a few moments through the waters of the lake, then bring it up and examine the contents. There I find, active and moving in all directions, these tiny crustaceans whose fate it is always to be the prey of greater creatures. I see them swimming, displaying all the details of their structure. And so I understand what happens in Nature. In their accustomed state they swim in the lake water as they do before me in that of the receiver; they are suspended in it, part of the plankton, and so float throughout their lives, peopling the waters with their hosts, ready to be devoured by those who have only to open their mouths and take them. The food offers itself, and the story of manna

falling from heaven, which on land seems absurd, has its true counterpart in the waters.

But I cannot complete my examination of these little prisoners in the boat; it must be continued in the laboratory to which I take them, and it requires all the methods of scientific technique. In every respect these little creatures are remarkable. The consideration they deserve is not limited to this peculiar relation of devourers and devoured; it extends to the peculiarities of their organic structure and its importance in the series of creatures in their group. Related to the great crustaceans, crabs, lobsters, shrimps and the like, as is indicated by their possession of jointed or segmented limbs, the segments of which can move one over the other; by their having a carapace which covers their body in whole or in part; by their breathing in the water; they show that they are crustaceans on a small scale not only as regards build, but in their general structure. They are, as it were, preliminary sketches, remote preludes, preserved from vanished ages until our own day. In this world of ours, they are survivors of the creatures which first appeared on the globe, and their multitude, their diversity, even to-day, give evidence of the power which established them.

Despite their unlikeness, despite the very appreciable differences in the details of their structure, they all look like members of the same family. They are small; the largest of them seldom more than a centimetre in length; the dimensions of the smallest vary round about a millimetre. Their body is translucent, sometimes absolutely transparent: it is their movement which generally makes them visible. All one sees of them is the black stain of their eyes, and a few coloured indications of their internal organs. Their thin, delicate carapace is also transparent. So are their limbs, often long and numerous, unequal in shape and size, bristling with delicate hairs projecting on all sides. With these they beat the water, making

use of them to swim in fits and starts, always remaining suspended.

Zoological classification, taking into account the differences in their organization, divides them into different species, genera, families, even orders. They make a considerable showing. Among them are found the Cyclops, so called because they have only one eye, in the front of their bodies, like the giants of mythology. There are also the Daphnias or water-fleas, whose body is sheltered beneath a large oval-shaped carapace, with long conical heads, large black eyes, and powerful bifurcated antennæ which they use in swimming. Other small creatures, too, are found among them, which, though their conformation is not the same, still belong to the same structural type.

Many of these species swarm at certain times of the year. Then hosts and hosts of them, sometimes dispersed, sometimes more or less gathered in shoals, spread over the waters of the lake. They make one think of the many swarms of midges one sees in a sunbeam beneath the shade of a tree on a fine summer day. Those tiny winged insects which go and come and buzz around, sometimes going off by themselves, sometimes gathering again and forming groups only to separate once more, offer a spectacle that is always changing, always moving. Held in the air by their wings, they remain until death comes upon them. From them we may get an excellent idea of the life and behaviour of these crustaceans of the plankton. Put water in the place of air, and limbs instead of wings. Extinguish the sunbeam and the brightness which do not befit an environment which gets darker as it becomes deeper. Increase the number of these suspended creatures, giving their swarms a numerical importance, a mass, which the hosts of midges in the air never suggest. Then you have an idea of what these planktonic hosts are really like, these groups of tiny swimming crustaceans, the intensity of active life

developed in the bosom of the waters and dispersed among this dust of floating creatures.

Their floating nature compels creatures like this to submit themselves to the various conditions of the medium which contains and supports them. The slightest current carries them along, so they prefer waters which are normally calm and relatively slow-moving. Variations of temperature affect them; they are more numerous in spring and summer than in autumn, and especially in winter. Light affects them unfavourably, and many of them try to avoid it. They hide themselves in the hidden depth of the lake 300 or 600 feet, sometimes even more, below the surface, for the Lake of Geneva is over 1000 feet deep in places. They go down during the brightest period of noon, when the light is very strong upon the surface waters. At night they come up again, and swim in waters they will leave a few hours later. These movements are constant and controlled; and they, in turn, govern the existence of the fish which exploit these little creatures, which are obliged to follow them in order to keep contact with the prey which they make their food.

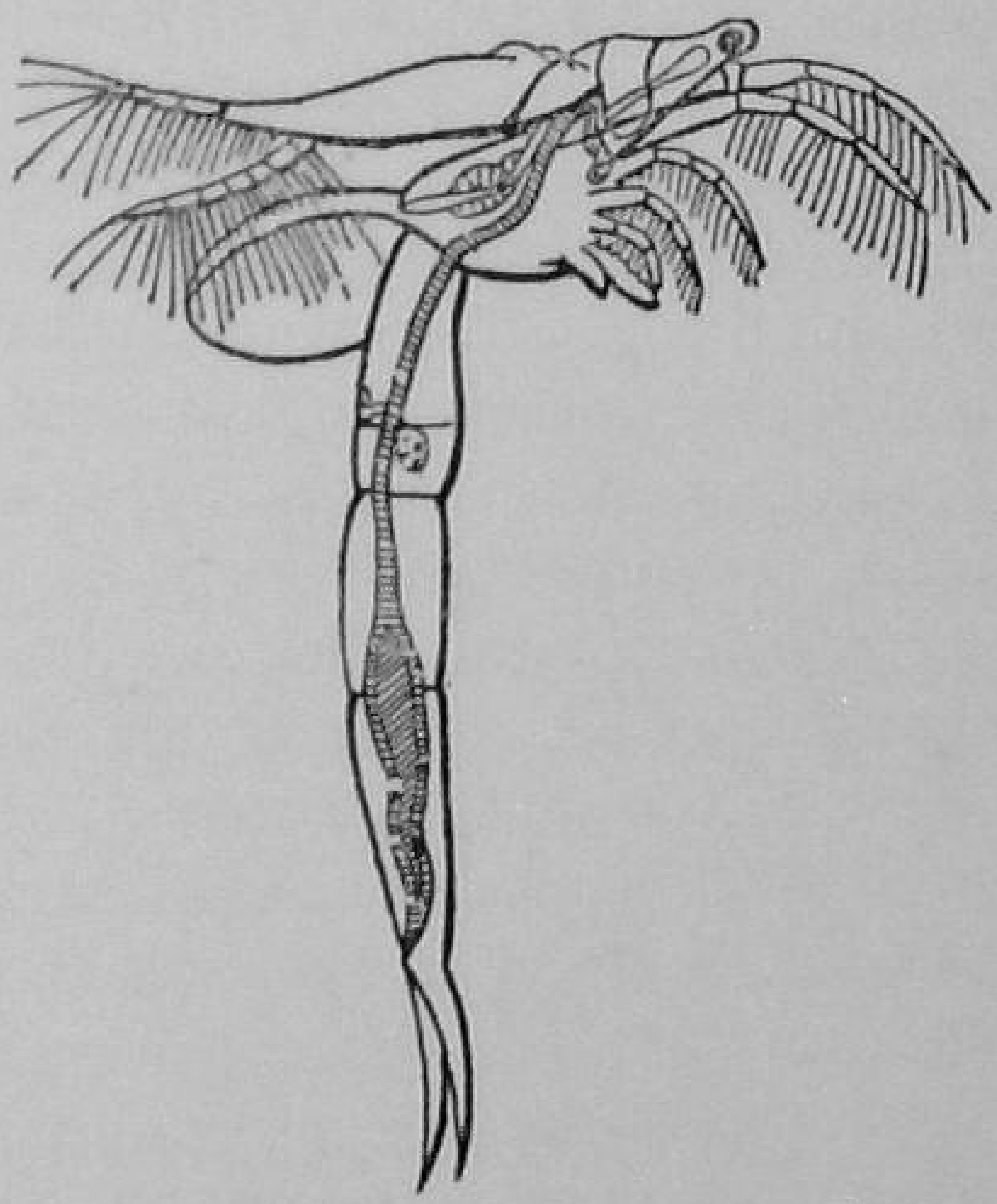

FIG. 34.—*Leptodora kindti* Focke, planktonic crustacean of the order Cladocera. The length is about half an inch.

But these prey, in turn, have to keep themselves supplied with food. Hunted down by the fish whose

sustenance they supply, they too, must live, and find around them, in the water in which they live, flesh upon which to feed. The cycle of nutrition in the lake does not stop at the tiny crustaceans; it goes on until it comes to the creatures, even more minute, upon which the water-fleas and their kind feed. We discovered in the stomachs of the whitefish what was left of their meals: now, in the stomachs of the little crustaceans, we see, under the microscope, the remains of the creatures upon which they have fed. These are protophytes and protozoans, unicellular vegetables and animals, invisible to the naked eye, but there none the less, in even greater numbers than those for whom they form the means of existence.

I take up the bottle which I filled when I threw out my plankton net. I bring it up to the level of my eyes and look through it against the light. There are the tiny crustaceans, swimming about in fits and starts, bolting about in all directions, but I cannot see anything else. The naked eye can discern nothing more. But if I go back to the laboratory, take a single drop of that water, and put it on a glass slide beneath a microscope of high power, I see great numbers of unicellular creatures whose size can only be measured in fractions of a millimetre. Nearly all of them are too small to be recognized by our sight; and under natural conditions we cannot distinguish them at all. Most of them are transparent or only slightly coloured, and this adds to our difficulty in seeing them: yet they exist, living, swarming, and people with their myriads of minute individuals the whole water from the surface to the bottom.

Tourists go into rhapsodies over the beauties of the lake. From their boat, as it moves smoothly over the calm waters, they admire the sky, the mountains on the horizon and, more than anything else, the water itself, that wonderful deep-blue water whose purity and limpidity they find so remarkable. But such

wonders, however glorious and magnificent, are not the only ones. There are others, of a greater, more mysterious beauty, of an extent as vast as it is unsuspected. And there is the wonder of the multitude of minute lives which the water contains, whose immense number makes up for the minute size of the individual. Not only is the water of the lake glorified by such magnificent shades of colour, flashing beneath the rays of the sun, but it is quivering with the life it supports throughout its whole mass. It is not inert, not simply mineral: it does not only reflect all that surrounds it; it is alive, active—each drop of it contains beings full of life, to whom it furnishes the wherewithal of existence.

These microscopic unicellular creatures, both animal and vegetable, live directly on the water which surrounds and contains them. They draw from it, without any intermediary, the material substances they require, in a state of solution. They form their living flesh out of inanimate matter. From it and through it they receive the warmth and light they need. Thanks to them, the water, most primitive of all environments, draws from itself the resources favouring not only the existence but the development of organized beings. It becomes creative. Essentially a mineral element, itself incapable of change, it yet engenders the changing and alterable flesh of living creatures. It confers the gift of existence upon the smallest, and so ensures, more and more closely, the existence of all the rest, including the strongest and most highly organized.

The cycle of nutrition in the lake is based upon these first creatures, directly maintained by the water itself under the action of the energies which pass through it. It is to them that are due the capacity and the virtue of collecting into one quivering flesh those mineral substances which, themselves inert, must constitute it as it develops, and increase its volume from the germ whence each develops. The cycle begins

with them and then grows progressively wider. The little crustaceans feed upon these first creatures; they, in their turn, serve as prey to the larger fishes, of which the divers species, according to their size and nature, live upon one another, hunting down and devouring one another. Then these last, so far as the lake itself is concerned, complete the series. The remains of the strongest, when at last they die, decompose, break up into their elements and go back to the mineral world. And the cycle goes on continually, always begun, always unfinished, bringing it to pass that all the inhabitants of the lake are more closely associated in

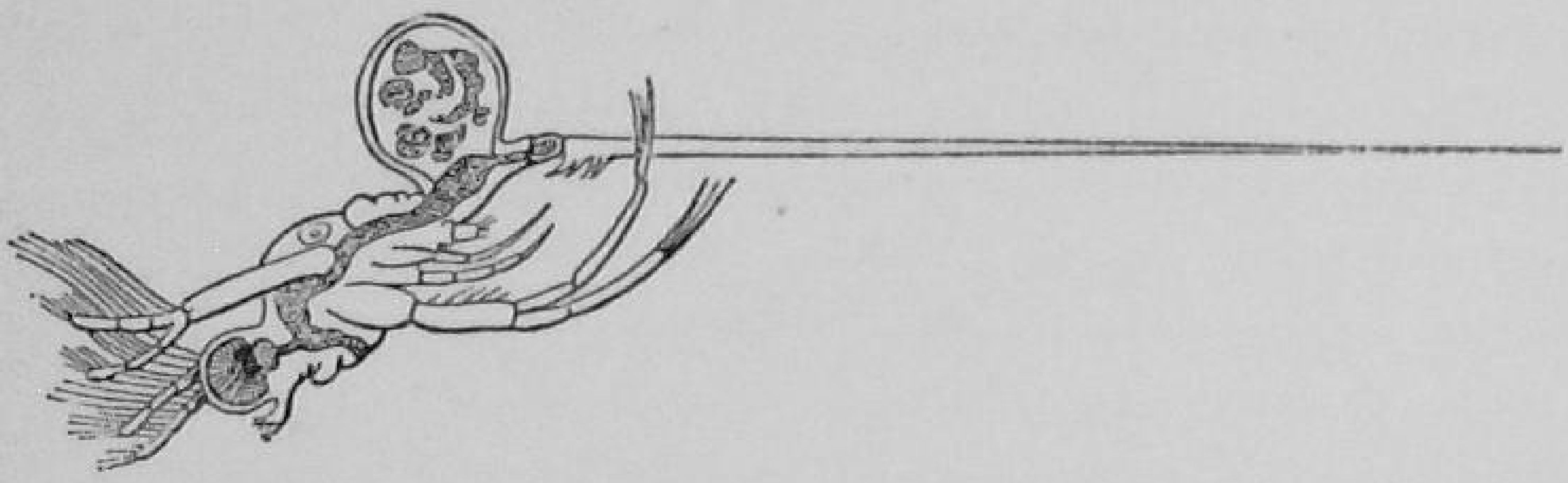

FIG. 35.—*Bythotrephes longimanus*, planktonic crustacean of the order Cladocera. The length, without the terminal appendage, is between 2 and 3 millimetres.

their search for subsistence. Beneath the peaceful sparkling waters of the lake, the depths are ceaselessly occupied by hosts of pursuers and pursued, in this continual chase after food, in this uninterrupted consumption of the flesh of one to build up the flesh of another.

We too are not indifferent to this state of affairs. When, at dawn, the fisherman pulls up his net, full of fish which he will send to the market—hoping to make a living out of the proceeds—he takes his share of the profits to be drawn from the whole cycle. For him, for us, the unicellular creatures, the tiny crustaceans, expend their vital energies, from which we can draw no advantage directly. The water which fills the lake: the sunshine which irradiates its surface

and is disseminated through its whole mass, delight our eyes and are utilized for our subsistence, placed at our service by these intermediaries which Nature has so well devised. We utilize them for our own purposes. Common sense suggests that we should see whether we cannot make better use of them, and actually increase production.

The Lake of Geneva is a limited area with a material equilibrium of its own. The water brought by the streams which flow into it and the water taken out of it by the Rhône, together with the evaporation which takes place, give it a fairly constant average volume estimated at ninety-nine milliards of cubic metres. It has an average balancing factor of vital population. The capacity having limits, the maximum possible absorption of sunshine has corresponding limits. Consequently, the direct maintenance of the microscopic beings which form the first ring in the alimentary chain is also constrained within certain limits. The quantity of these creatures cannot exceed a definite quota, and this quota is fixed by the very conditions of the lake. Their number, their capacity for increasing, are not limitless; they stop at a mark past which they cannot go. The other rings in the chain are affected by this first condition; they, too, cannot go beyond the limits assigned to them. There are thus natural limits to the total production of fish, and these are laid down by the cycle of nutrition. Production may fall below, but it can never rise above. The quantity of the plankton, the mass upon which the rest is maintained, is the governing factor.

It is a more powerful and effective factor than it seems. If the open water fishes, whitefish, char, trout, depend entirely upon it; those of the shore waters, and of the bottom, perch and pike, do the same. The greater devour the smaller all through the scale, feeding upon corpses or fragments, but the smaller, who maintain the rest, find what is essential

for their subsistence in these creatures. In the cycle of nutrition, the plankton is the foundation, and the rest follows from it. According to its annual alternations, its phases of prosperity or diminution, the fish population, maintained and nourished by it, increases or decreases, each species finding its own manner of life and its own particular principle of existence therein.

Mediæval medicine had a word, now no longer used, which expressed the capacity of an organism for alimentation and assimilation. It was taken directly from the Greek word "*sitesis*". It meant the power which a creature possesses within itself, to exist by feeding itself, and the variable rate of that power in its equilibrium of complete existence. To avoid periphrasis we may perhaps revive the word here. The lake, as regards the food-supplying capacities of its water, has its ratio of sitesis, its definite capacity of providing nourishment. This determines the size of its population, and keeps it within the bounds it fixes. Its capacities are not indeterminate or unlimited.

What is true of the lake is true of other stretches of water of the same type, and of the streams which enter it. Each, like it, makes up a realm with an alimentary capacity of its own, its sitesis, on which depend the abundance and diversity of the species which dwell in it. Some base it entirely on the tiny floating creatures: others add to it the further resources provided by the shores and land, and the larvæ of insects or midges and the like, which fall into the water. But they all follow an identical principle, that of the chain of devourers and devoured, of the equilibrium of alimentation, of the mutual dependence of all, down to the tiny creatures who form the basis of a vast edifice of nutrition. A stream rich in fish is one whose waters contain a store of nourishment sufficiently abundant for them; and we cannot get much from a

watercourse, however limpid and pure, if circumstances prevent it from having an adequate average sitesis.

When we see a broad and mighty stream from which the local fishermen daily take a goodly number of fish; when we consider the ease with which these fish, hitherto unseen and hidden, are taken from it, we cannot help thinking that the water might hold more and produce more, taking into consideration the extent and depth of the space in which they live. It looks as though this space alone counted, and that its vastness might easily contain more than the production we actually secure and consider rather low. But if the water contains, if it might contain still more in the space which its bed occupies, it does not nourish. It can contribute nothing directly to the nutrition of the fish. It can only do so through creatures interspersed in the cycle of nutrition, beginning with those which are at the lowest point, and hold the first position. They alone count. And if we think of restocking by means of new fry; if we try to increase the regular population because we deem it insufficient, we must take this cycle and its equilibrium into account, with its capacity and its sitesis. We must give due value to all these considerations and act according to the results obtained. The analyses of the plankton, as regards both quantity and quality, make clear the line we should pursue, giving us, as they do, the necessary preliminary indications on these points.

We have used the Lake of Geneva as an example. It is a great sheet of fresh water, extensive yet not too large, and it offers a norm which will help us to realize what exists in other places. In its waters the cycle of nutrition, with its chain of circumstances, its equilibrium, its correlation, appears in a clear and striking fashion; accessories and secondary considerations taking a less important place. It unveils itself here with a clearness unequalled elsewhere.

The waters of the sea also have their cycle of nutrition, their progressive chain of devourers and devoured. The stomach of a sardine, opened so that we may find out what it has in it, shows us the remains of microscopic vegetables and animals, mixed up with fragments of floating creatures a little larger. In the stomach of a herring, as in the whitefish of the lakes, we usually find traces of those tiny crustaceans which, themselves a part of the plankton, millions upon millions of them, feed in their turn, upon microscopic

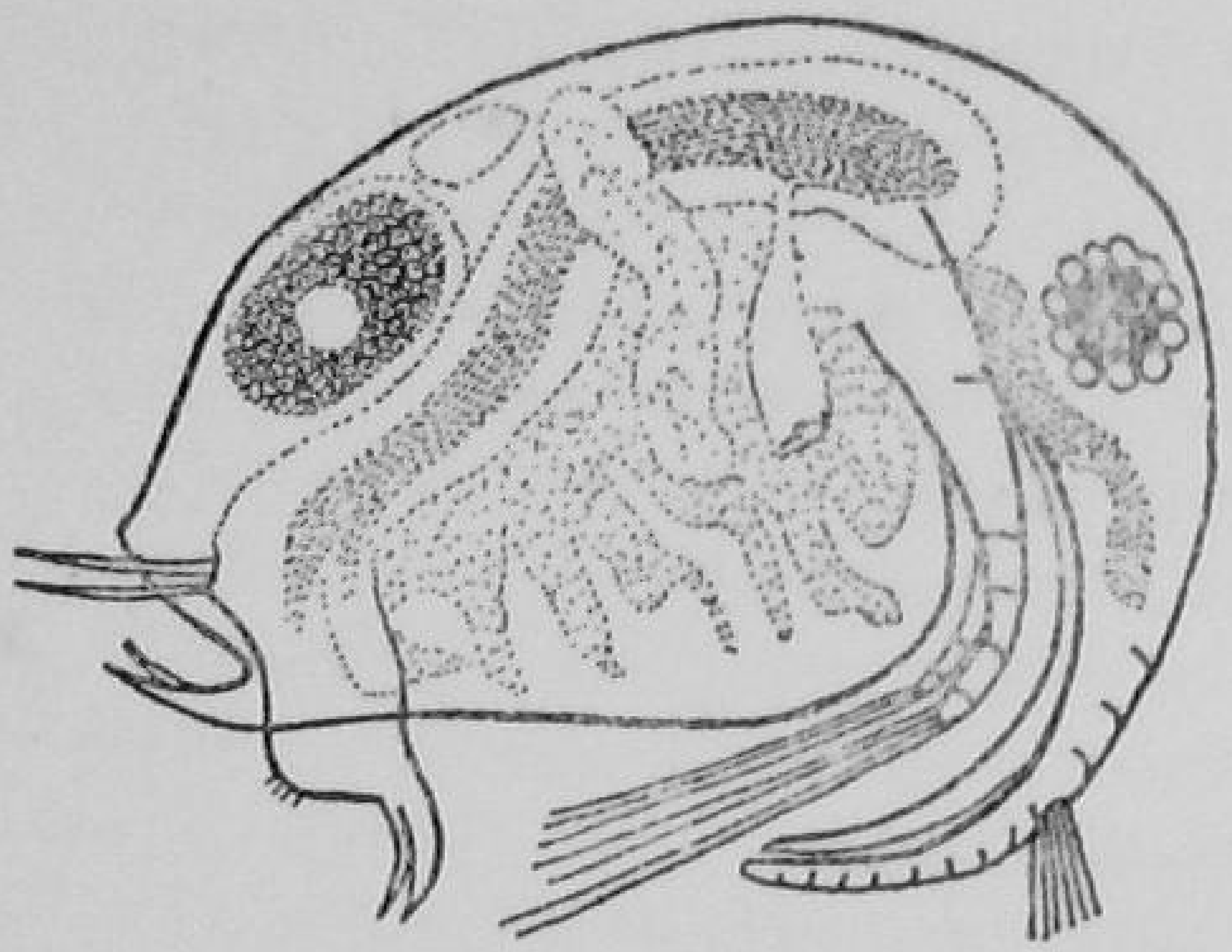

FIG. 36.—*Bosmina longispina*, planktonic crustacean of the order Cladocera. Length between ½ and 1 millimetre.

unicellular creatures. The cycle, beginning with the latter, is continued by the little crustaceans and by the creatures, as tiny as these last, which also feed upon more minute beings. It continues again with the stronger animals, not sardines or herrings alone but belonging to other groups, molluscs and higher crustaceans. It goes on to still larger animals, like the tunny, which ruthlessly hunts down the anchovies, sardines, and mackerel. It ends in the giants of the sea, huge sharks, enormous whales like the cachalot. It is completed and complicated by the huge quantity and diversity of the animals which live on the bottom, settled there or practically so, which also take their

share of the feast, and form so many secondary links in the chain.

The sea, in its enormous mass carrying to extremes what the lake can only sketch on a much smaller scale, clearly expresses the reality of things. There are no large plants in it: the true herbivorous animals have no place there. Only animals confront one another, animals compelled to feed that they may live, devouring one another, the larger the smaller, the stronger the weaker, each serving as prey to another. So down to the most minute microscopic vegetables which are directly maintained by the environment upon which this prodigious meal is finally based. Their flesh, passing from body to body, is continually changed, carried hither and thither, modified all the time. The living substance of which they are composed, ceaselessly taken and retaken in this alternation of devourers and devoured, goes from one to the other in a continual cycle of nutritive exchanges. All, bound together by their need for nourishment, make mutual use of transformers. The whole vast mass of the waters in its depths, in the darkness which reigns there, is the scene of one fearful massacre, one eternal sacrifice. In its abysses, going down all the way from the surface, the fight for nourishment goes steadily on, a grim and merciless struggle.

The contrast between the waters and the air is very great here. In the air, on *terra firma*, directly and brightly illuminated by the sun's rays, the struggle for food goes on as it does in the water, but it is less urgent. The vegetable kingdom, which is necessary to the subsistence of the animal kingdom, has a more important place: the destruction of the plant, in the feeding of herbivorous animals, does not entail such disastrous results. The carnivorous animals have not a predominant, or almost exclusive, part. The cycle of nutrition exists indeed, but the struggles which accompany it are neither so many nor so impressive.

On the other hand, the waters show us more forcibly, in a simple and elemental way, that the world of the living, taken as a whole, is a vast place of nutritive exchanges, in which the brutality of shock and encounter is still tempered by the necessity of bringing their results into general equilibrium, so that everything may be duly conserved.

The living world is maintained at the expense of the mineral world. When the life of individuals comes to an end, the matter of which they are formed decomposes, breaks up into its original elements, returns to, and becomes a part of, the inert, inorganic environment. So, to make up for this, life must keep taking from that environment the same elements which it ultimately returns to form the substance of those beings which go on living. This is the beginning of the general cycle of alimentation. This analytical process of dissociation postulates a corresponding process of synthetic reconstruction, in which the primary elements are gathered to form the flesh, and to maintain it by feeding. Animals are incapable of such a synthesis because, in their nutrition, they must employ flesh which has already been formed, and groupings of elements which have already been made. Consequently, the vegetable kingdom has had to take on this work of recomposition. Without it, without this re-forming reaction, brought about under the impulsion of solar energy, the animal kingdom could not subsist, herbivorous creatures could not browse, and carnivorous animals would not be able to feed. This is a general condition, which makes even more clear the contrast between the world of the waters and the world of the atmosphere.

In the latter, the preliminary, essential synthesis is carried out by the many vegetables, of all kinds and sizes, which cover the surface of the earth, and make it a pleasant place to live in. The herbivorous animals eat the grass of the prairies and meadows, and browse

upon the leaves of large trees; the great family of insects lives at the expense of the plants on which it settles; the links of the alimentary chain are but few. In the former, on the other hand, there are no great vegetables, or they are found only in small areas near the shore; the initial synthesis, which is the beginning of everything, cannot be based on them. It is carried on by the microscopic, unicellular vegetables of the floating plankton. In spite of their individual minuteness, the tremendous abundance of them provides all that is needed. The alimentary cycle begins with them and, since they are so small, necessitates several degrees or stages. There we find it as it actually is; we realize how necessary it is, and how it consists of a progressive series of successive episodes. Life in the world of the waters, among the beings which make up that world, shows us in greater fullness, both its requirements and the power it has to fulfil them.

I have said, in my study of Daubenton, the founder of Zootechnics, that the full activity of living Nature consists in a continual series of exchanges of substances and forces, of matter and energy. These exchanges originate in the inorganic world, at the expense of the elements which compose it and the radiations which traverse it; they are carried on between individual and individual; they become more or less vigorous as circumstances ordain, and finally end in the destruction of death and the return to brute matter. It is an endless cycle, always ceasing and always being renewed, and in it the creatures of the living world are themselves the bases of the exchanges, while the effecting of them is itself their life.

The best defined and most obvious of these exchanges is concerned with food. If creatures are to grow, they must first produce the matter of which they are composed, and then maintain its integrity in spite of the fact that it is always being used up in

the course of their lives. They find it about them. The smallest and simplest of them draw its elements directly from the inorganic world; the others take it ready made from creatures like themselves, which they consume as prey. The chain of devourers and devoured is thus begun, the chain by which living matter passes successively into all, and incorporates itself in them. The smallest are the beginning and the end; the bond begins in them, and with them it is completed. Their swarming mass, on land or in the water, takes the predominant place.

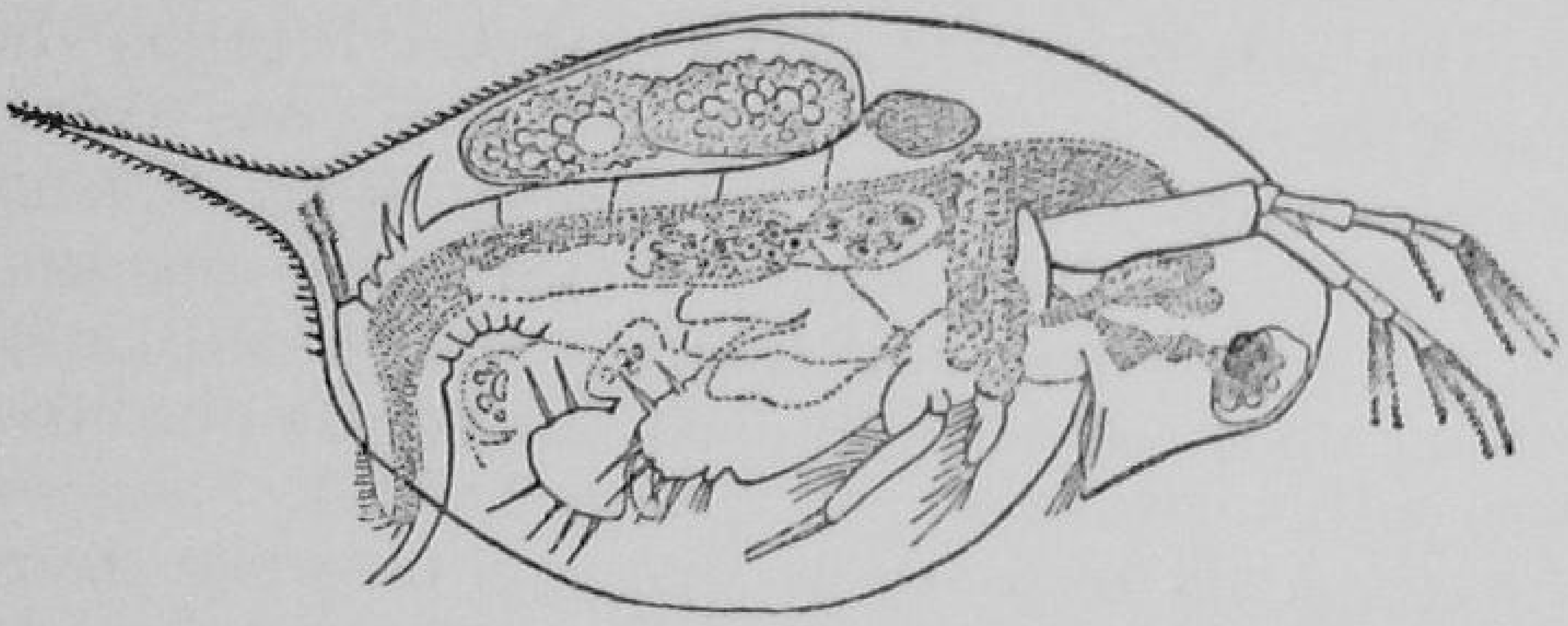

FIG. 37.—Water-flea (*Daphnia pulex*), planktonic crustacean of the order Cladocera. Length between 1 and 5 millimetres.

The carnivorous animals devour the herbivorous, and these eat the plants nourished by brute matter; their death makes everything brute matter again. Each, compelled to take its place in this chain, has a purpose there; Nature takes it as one link, and that is all. Living matter thus acquires a life of its own, independent of personal existence, and having its origin in a life of general alimentation, in which creatures play the part of alimentary transformers for one another. The plant gathers mineral elements and forms its substance out of them; the herbivorous animal modifies this substance and reconstitutes it in itself for the benefit of the carnivorous animal. In the general economy these different forms of flesh are destined to be the objects of nutritive exchanges. The

living world, taken as a whole, thus appears as a vast series of ceaseless transformations, continual exchanges of devoured flesh, in which each has its definite place. There is a metempsychosis in this cycle of alimentation; the creature does not become dust until it has transformed its substance into that of other individuals.

Our eyes can only see the surface of these deep abysses of the seas and lakes, filled with dense water and so gloomy that not a gleam of light penetrates them, so different from the earth which is illumined by the sun's rays, and has only a light covering of air; but the mind of the naturalist, employing the aid of research, can penetrate them, throw light upon their mysteries, and learn their secret. It finds there a profusion of life, a diversity of form, a power of action, which have no equal in our immediate surroundings. There it discovers a law, which is less obvious in our world, though it none the less commands obedience. Despite the apparent paradox of their darkness and remoteness, it is in them that the naturalist comes nearest to the meaning of life, for that meaning evidences itself there more clearly. The abysses have kept their original conditions, which are disguised or not to be discovered elsewhere, and the smallest piece of evidence drawn from their study gives a certainty which could only be secured elsewhere with considerable difficulty.

The living constantly masters the inanimate; living nature exploits inert nature. It ceaselessly returns to it but, equally ceaselessly, it takes from it the substances it needs to form itself, and the forces which it must have if it is to subsist. Moreover, exploiting itself too, it ranges its objects so as to make them use one another for food. It is neither ill-disposed nor indifferent, but arranges all things so as to continue its exploitation and keep itself alive; it considers each of its creatures as a pawn on its huge chess-board, and establishes them all in time and space in conformity

with its aim, which is to endure. As in a battle, units are sacrificed one after another and then replaced, but the victory is won for the advantage of all.

This victory is that of conserving life despite the necessary destructions. The species of the globe, in their continual struggle, though they meet and engage in warfare, yet realize a sort of equilibrium, of inter-dependence among themselves, which enables all to survive and to last, in spite of the changes and chances of their struggle. The strongest cannot gain too sweeping a victory or they would lose the prey on which they feed. The weakest cannot go too closely to the wall, or their absence would be felt. There is a general co-ordination, so that all exist side by side, so that in the living world, with its continual disappearances and renewals, there is brought into being a permanent, constant whole, which is renewed of itself, always created, always populated.

Living nature has a morality of its own, which will not suffer the strong utterly to destroy the weak, and prevents them from going too far. It has its system of relief, which tempers the over-vigorous manifestations of any one section, and keeps them within the necessary bounds. Nature has a justice of its own, which brings all existences beneath the same yoke, and gathers them, in time and space, into one harmonious whole within the governed order which it has set up. Under the desperate struggles, beneath the ruin and distress which these struggles cause, we can discern that morality, that solidarity, that justice; we see them in their omnipotence, recognize their results, and use them to our own advantage. Man, become the conqueror of the living world, the dispenser of the forces of life, is also their beneficiary. He must, if he is to assure his conquest and to extend it, observe the laws inscribed on all the natural objects around him.

The feeling of serenity, of glorious, tranquil peace,

which comes from looking upon a beautiful lake beneath the setting sun, is only deceptive in appearance. It is true and it is real. If at first we seem to find only evidences of violence and destruction which incline us to alter our original feeling, that feeling later comes back again, even more intensely, now that it rests on a surer foundation. It arises spontaneously from the world around us, and is in perfect harmony with what we feel within ourselves. Mind and heart combine in admiration before that majestic spectacle, and they are justified. Nature, always striving after progress, Nature, the benevolent sovereign, superb reflection of the creative will, presents herself to us all conciliation, all appeasement, all kindness.

CHAPTER XII

THE SUN-PERCH AND THE CATFISH

Two fishermen, father and son, the older already growing grey and the younger still a youth, were sitting on the bank of a river, keeping an eye on their floats. They watched keenly for the slightest sign of a bite. Suddenly, one of the floats moved sharply, whirled round and round, and literally went down like a shot. The older fisherman seized the line, gave it a sharp tug to hook the catch, then pulled it out, bringing to land a quivering little fish which sparkled in the sunlight. He let it drop on the grass and looked at it with some disgust.

"Another of them," he said. "We've had nothing but this rubbish since we started. And there's about five pounds of them in the basket already. Put it with the others," he said to his son, "and let us finish. I've had enough. These sun-perch are more bother than they're worth."

"I'm with you," his son said. "But there's a certain amount of fun in it. You've only to bait the hook, throw in the line, and you get a bite and a fish at once. It's true they're never any size, and they don't look much when they're cooked. But they are pretty when they come out of the water, and as we get so many of them, they don't make a bad dish."

"Yes, yes," grumbled the father. "But they're not so good as all that. Not much flesh and too many bones. How different from the genuine perch we used to have, which these new imitation perch have chased away. They were really plump and well fleshed. In this very spot, I've sometimes caught one weighing

more than a pound. But that's almost twenty years ago. There's been a change since then. The river is very different now. There are fewer fish in it, and they're not the same fish."

"How has that come about?" the son asked. "These new-comers haven't come without some reason. Something must have given them the opportunity. What was it?"

"I know what it was," said the father. "Indeed, I'm partly responsible myself. I've sometimes talked to you about the old friends with whom I used to

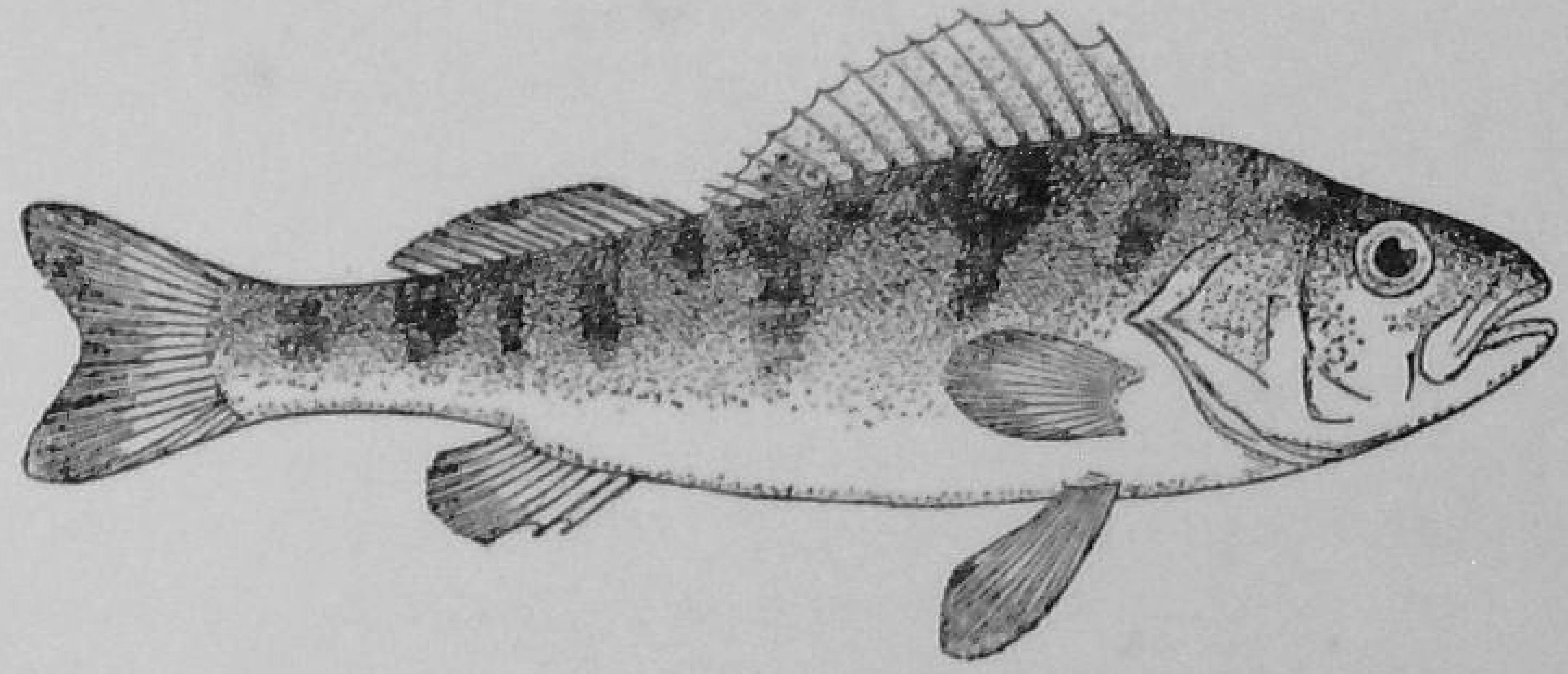

FIG. 38.—European Perch. Usual length between 8 and 16 inches.

fish and hunt when I was a young man. We're getting on now and we don't often meet in these days, but we used to be very keen, and all we cared about was our sport. There never was enough game or fish for us. And we thought we could improve on Nature, give her a hand, so to speak. It would be enough, we thought, if we put into the water young fry from the breeders, and we should reap a glorious harvest later on. We could already see the streams richer in fish; the smallest brook, we imagined, would be full of fish. And so, like many other people, we set about stocking these waters.

"Since we ourselves were doing the stocking, we could choose our fry. We fancied that our native fish, which were decreasing in numbers all the time, were

not as fertile as we desired. Then we thought of exotic species which, since they did so well in their own native country, offered certain guarantees of plenty and fruitfulness. So we did a job of acclimatization. Now you see the results—a basket full of sun-perch. Not another bite have we had, neither true perch nor bleak; not even a common roach."

"But it was a good, sound idea all the same," said the son. "The rivers were getting short of fish, and it was only reasonable to try and fill them up again. And as you had the opportunity, the fry at your disposal, and the necessary means of transport, you were surely right to make use of it. Besides, you made a good choice.

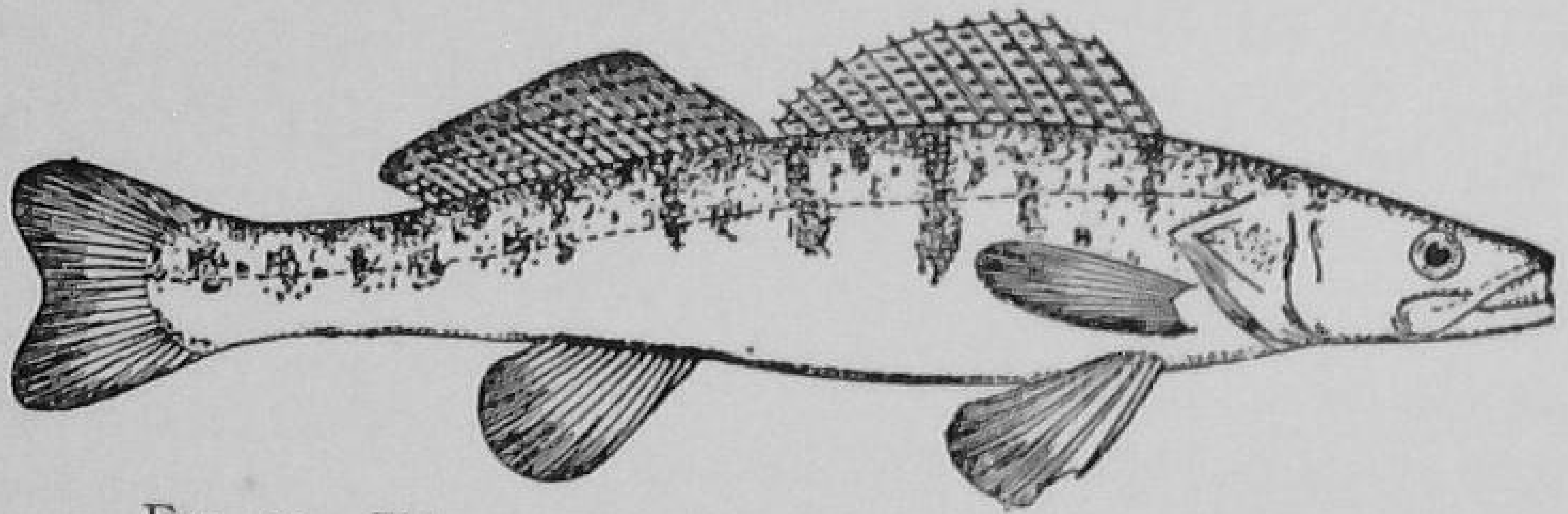

FIG. 39.—Pike-perch. The length may be over a yard.

If you were going to stock the river, it was better to use good stock, strong species which reproduced well, rather than species already on the down grade."

"When I listen to you," the father answered, "I seem to hear the exact echo of what we used to say, and wrote and printed in our fishing papers. We thought it was splendid, and we started off in fine style.

"These attempts to acclimatize and restock were not new. The methods had become known; we had only to apply them, only to profit by experiences hitherto confined to small species. We agreed almost unanimously to discard species from warm countries, like the barbel and the gourami which, however prolific, could not possibly hope to survive in our cold waters during the winter. We decided on a country, the United

States, with a climate rather like our own, and we thought we should be safe. There, the authorities, who had specialized in fishery work, were getting excellent results with a certain number of species they used for the purpose. We thought, if we imitated them, we should get the same results. We sent for eggs and fry. And now, thirty years afterwards, we know where we are. The results obtained vary; there are both gains and losses. There have been gains so far as the general principles of pisciculture are concerned, but we common or garden fishermen have decidedly suffered as regards the most highly valued joy of all, fishing in waters free to all.

"I remember all the heated discussions, the arguments of all sorts that were bandied about. Each species proposed became the object of relentless criticism; it was praised to the skies at one time and abused at another. Each suggestion was absolutely and thoroughly sifted. In this water at our feet, where, like the rest, I took a hand in the matter, I can see all those species again. Some have disappeared; some only survive because they are given continual attention. Others, like the sun-perch, have definitely settled down and established themselves.

"I remember that glorious salmon[1] with which we hoped to make good the gradually increasing losses in the native salmon[2] of our rivers. It came from California, whence its eggs were obtained, and it was called after the country of its origin. It abounds there, and every year at the appropriate season, thousands of individuals band together, leave the sea, and go up the rivers to spawn. We hoped to have the same success, so much the more as the species, which is a strong one, easily accommodates itself to the confined life in the breeders' pools. But our hopes were vain. We secured suitable fish to breed from and got spawn

[1] *Oncorhynchus tschawytscha*, the Quinnat or King Salmon.
[2] *Salmo salar*.

from them by artificial fecundation; we let the fry grow and it did very well. Then we put the fry into the rivers hoping to find them again later, after their stay in the sea where they fatten. But nothing of the sort! In California and Alaska the young fish go back to the streams from which they originally came, but these we thought we had acclimatized never came back.

"Nevertheless, if we had bad luck with the salmon, we made up for it with the trout and char. At fisheries exhibitions I have pointed out to you these magnificent fish, good-looking and fine specimens which would take a very high place among the show species, if markets

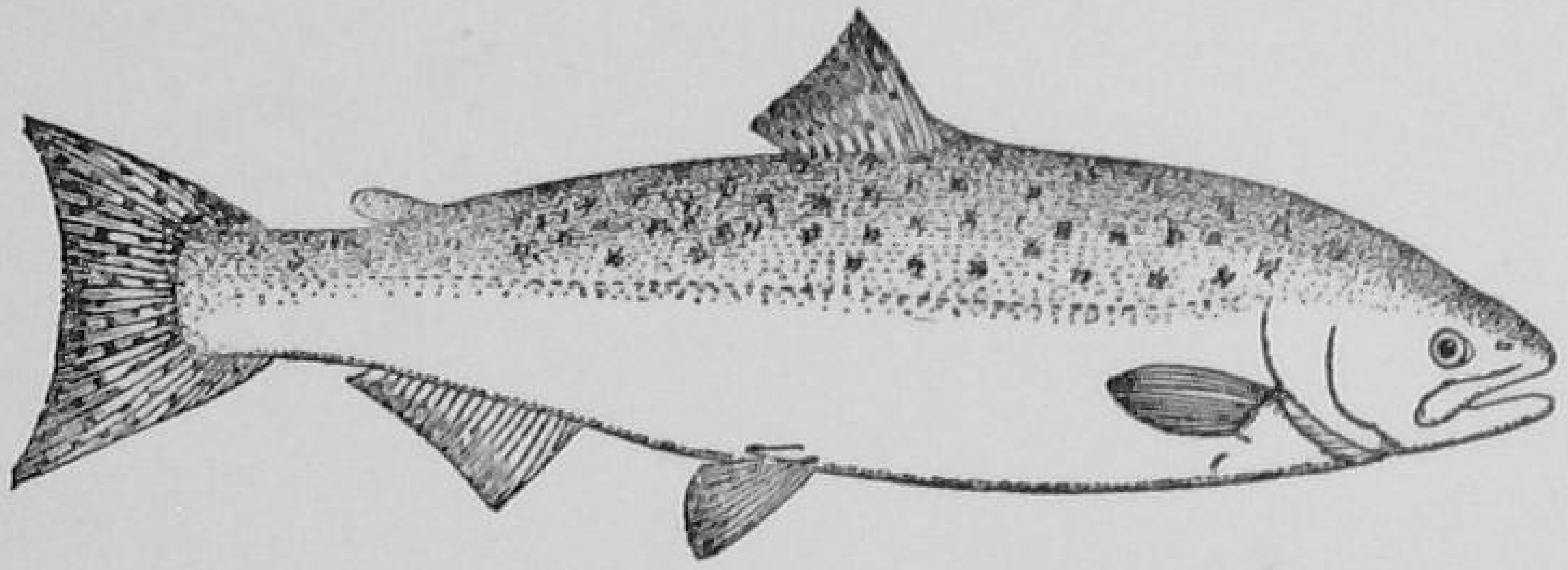

FIG. 40.—Californian Salmon, Quinnat or King Salmon. Its length may be more than a yard.

and kitchens did not get them first. The rainbow trout[1] comes to us from the United States, and its name suits it admirably. When it swims in its wavy course in the water of an aquarium, it seems as though adorned with all the colours of the rainbow. The dark greenish-blue back; the sides of a lighter blue surrounding a purple band; the white belly, with black markings over almost the whole body, give it, with their iridescent flashes, a most glorious livery. Yet, in spite of its beauty, its companion, the fountain char,[2] even surpasses it. You remember having seen one, with the stripes which cover its back and the tops of the sides. Both pattern and brilliance are indescribable. Its

[1] *Oncorhynchus irideus.*

[2] *Salvelinus fontinalis.*

scales combine the most gorgeous sparkle with an astoundingly varied wealth of colour. It is indeed a moving jewel.

"With these two species we made a definite advance. They are really useful. They are not so difficult to raise as our native trout; they grow more quickly, and are easily collected and fed in the tanks where they are raised for the market. But this is as far as we can go. If any attempt is made to restock free-flowing waters with them, it almost always fails. The fisherman waits for results, but he is invariably disappointed."

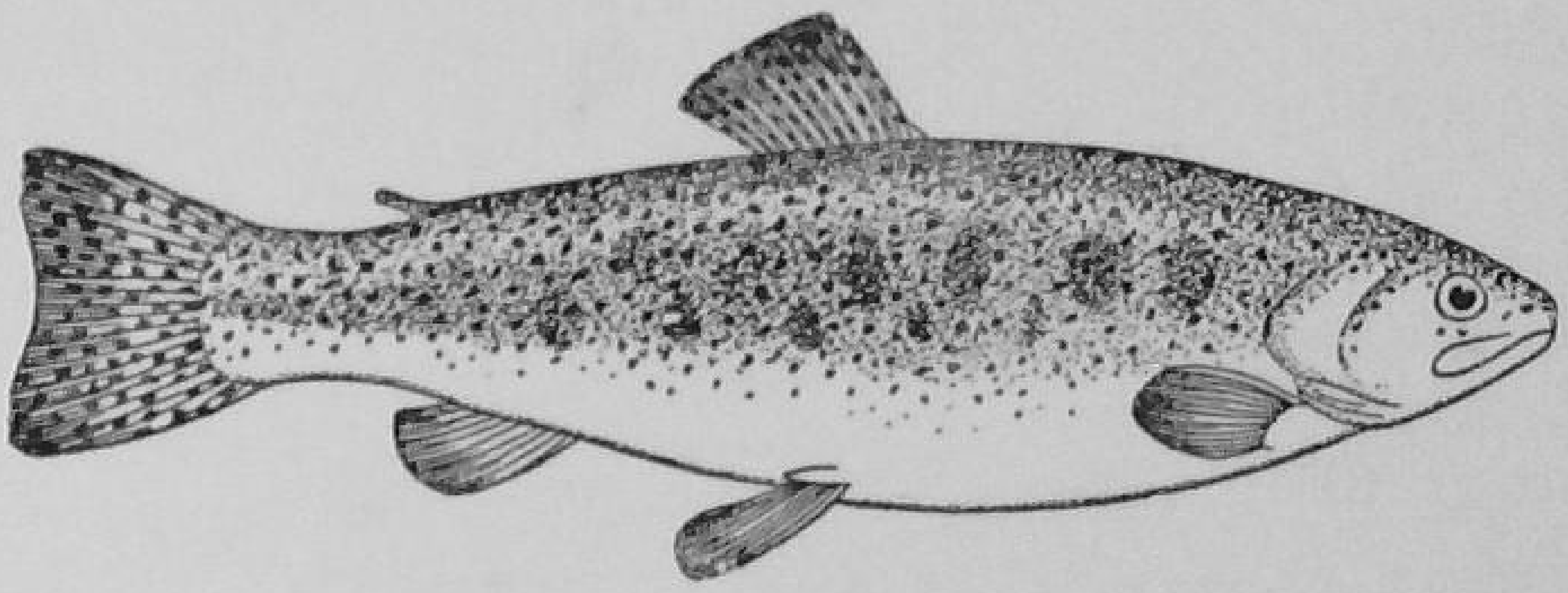

FIG. 41.—Rainbow Trout. Its length may be as much as 2 feet.

The young man interrupted him. "But why? If these fishes accommodate themselves so well to a confined existence, where one would expect them to perish just because they are confined, why don't they get on as well, or better, when they are in free water, with unlimited room to move about?"

"I'll tell you why in due course," the father replied, "but I must first complete my account of our attempts at acclimatization. Meanwhile, I can throw some light on the matter by making a comparison. Think of the other animals we breed for our own purposes, animals which can only exist so long as we look after them, and would inevitably perish if we set them free. The slavery of domestication is absolutely essential to them. Look across the river at the turkeys and guinea-fowl pecking about in the meadow on the other side, looking

for insects in the grass. They too are acclimatized, like the rainbow trout. They can live easily enough in the country from which they come, but not here. Here they need continual looking after. They must be fed; the results of all this pecking are only a sort of dessert. Let them loose in a wood, and they would very soon disappear because they could not find the nourishment they need. To acclimatize them means to make them slaves from birth.

"The rainbow trout is not alone. The only fish we have succeeded in taking from the United States have belonged to the salmon family. Others have been tried, notably the perch of that country. One of these species, the black-bass,[1] is worth considering because of its excellent flesh. It may weigh as much as four pounds. Its body is oblong and corpulent like that of our native perch, but it has several rows of black along the back, which are peculiar to it, and make it easily recognized. It is a really fine fish. The only fly in the ointment is that it cannot live in most of our streams, as our own perch did when it was common. Its food requirements are considerable, proportionate to the rapidity of its growth, and it must have abundant nourishment or it will die. It only manages to survive in a few places, lakes or canals, and is mainly found in the ponds of the fish-breeders. This brings us to our sun-perch,[2] which belongs to the same family, but to the smaller varieties of it. The name 'perch' is given to a certain number of species, sufficiently different as regards detail to justify their being divided into several genera, but alike as regards behaviour and appearance. The sun-perch is an ornamental fish. It shines with every colour. The greenish-grey and blue tinges of its back merge into the orange and golden-flecked purple of its sides, which are further marked with darker zig-zag quadrilaterals. All this splendour is enhanced, especially in

[1] *Micropterus salmoides* and others.
[2] *Lepomis megalotis*.

the males, by a large scarlet-brown spot on a sort of flap which prolongs the cheek backwards. It is really beautiful, whether we watch it quivering when it has just been taken from the water, or in a tank in some aquarium. It is unfortunate that it has a flattish body and poor flesh, that it never grows to any size, and that the best specimens are scarcely larger than my hand. Without these defects, it could only meet with approval.

"Anyhow, in becoming acclimatized, it has given proof of a tenacity which indicates considerable strength. It has become European, and takes its place among us with an ease which its companion in origin, the black-bass, never seemed to display. By itself, by its strength alone, and given over to its own devices, it is progressively extending its domain, enlarging it from affluent to affluent, taking advantage of the flood waters, passing through the canals, and finally reaching places where its presence would never be suspected. It suddenly appears in places where nobody ever put it. It colonizes by imperceptible means. Its advance is not regular, for it does not always meet with the same obstacles; it has its ups and downs; but, generally speaking, it is continuous. Circumstances sometimes favour and sometimes restrict it. Sometimes we find it abounding and almost succeeding in chasing away the other species, which is what has happened in our river; then, years afterwards, it goes off in numbers, and then appears again. Although acclimatized, it is not yet so much so that it is indifferent to external changes; indeed it seems excessively sensitive to them, much more so than our native species, which have had a longer experience. According to the year, to the seasons and their varying severity, spawning and the development of the fry proceed differently, and the years that follow indicate this by the numbers of the fish that appear. In one and the same place the species succeed either to themselves or to one another in accordance with these alternations.

The sun-perch, above all others, vacillates with these contrary impulses.

"What about its rival, the North American catfish,[1] which is even stronger and more robust? Of it we can say that it knows no obstacles, and that in its efforts towards expansion, it has never met with defeat. Its appearance is not exactly attractive; but, on the other hand, it has a strength, adaptability and capacity for survival which overcome all obstacles.

"What made them bring us that particular fish? In central and eastern Europe we had already a representative of the family of Silurides, one of the giants of the family,[2] the wels, and there was no particular reason to acclimatize one of its small members. It has neither grace nor beauty, for its body is slimy, its large flat head provided with barbs that look like a cat's whiskers, and its colouring bottle-green or yellowish-grey. If it made up for these inelegancies by the quality of its flesh, we might forgive it, but it does not. Its head is too big and its body too small, and this means that there is very little that can be eaten. And even what is available has no especially attractive qualities. You can imagine the disgust, the disappointment, and the grumblings of those whose streams and ponds were gradually invaded by it. And complaints were all the louder because the creature, being poisonous, is dangerous to handle. On its dorsal fin, and especially on its pectorals, it has strong, pointed spurs, which may deliver a painful wound which takes a long time to heal.

"It was all to no purpose. The species likes temperate waters, quiet waters over a muddy bottom. There are plenty of these in our country, and it is gradually taking possession of them, all of them. Like a cat-burglar, it seems to find its way anywhere. It holds its own and progresses at one and the same time, in places where any other fish would decline and disappear. It is the equal of the eel in this respect, and that is saying

[1] *Amiurus nebulosus.*

[2] *Silurus glanis*, Linnæus.

a good deal. Like the eel, it can dig itself into the mud of a pond for weeks and months at a time, brave the droughts of summer or the cold of winter. Like the eel, it can adapt itself to waters of every kind, even the foulest, provided it can satisfy its hunger there. The slightest little trickle of water is sufficient for its fry when they are young and small. In certain places where there are carp-ponds, the presence of this species has become a genuine plague, interfering with breeding and compelling the breeders to take expensive measures to counteract it. Yes, all in all, this catfish is not exactly an acquisition to be proud of."

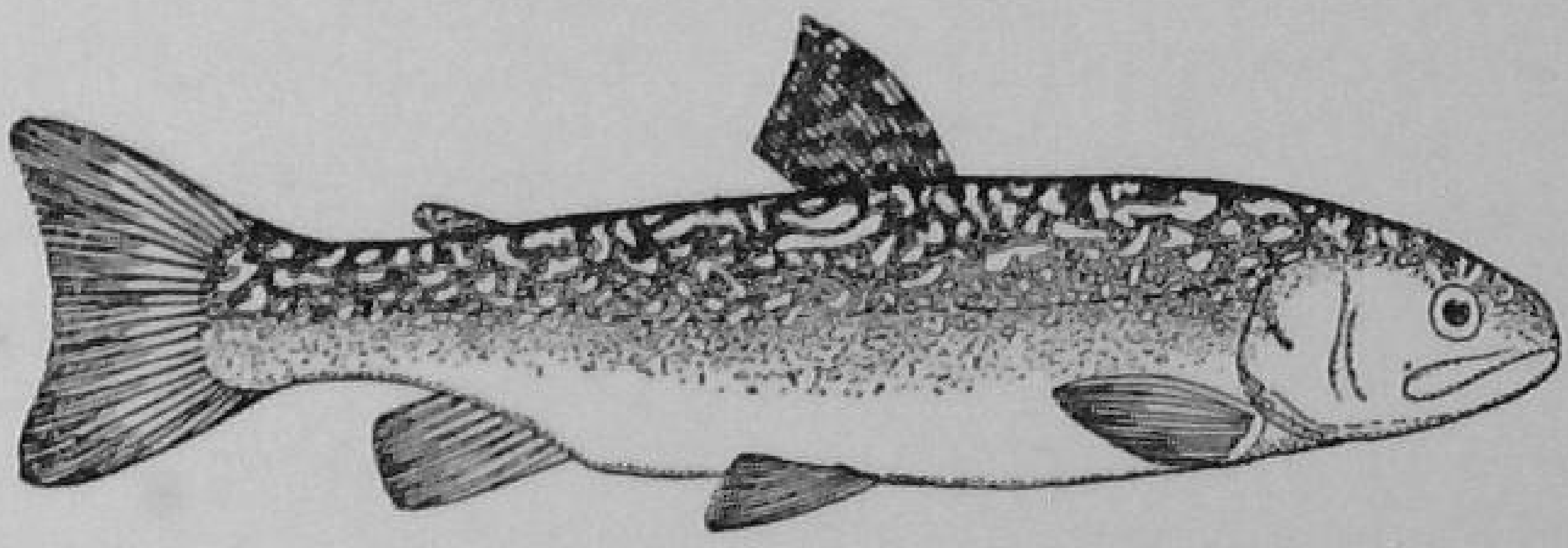

FIG. 42.—The Char. The usual length is from 10 to 20 inches.

The son was sitting on the grass, leaning against a tree, listening attentively and enjoying the shade so conducive to conversation. "There must be a reason for these curious differences," he said. "How is it that some of the acclimatized fish get on well while others don't? In the country of origin they are on the same footing; they all live quite well there. It is surprising that when they are transplanted elsewhere they get on so differently. What is the cause of it?"

"That's what I was getting at," replied the father. "I will tell you as far as I can. I will begin with a comparison. Think, for a moment, of the body which all creatures possess. It is made up of juxtaposed organs, each with its function, fulfilling that function in order to play its part in life as a whole. Again, each of them has its own shape, its own structure, its own size; there

is no competition between them. All are fashioned for the work they have to do, and their particular condition is thus determined by that of its neighbours. To this state of affairs we give the name ‘ organic correlation ’. There is equilibrium among all. If one were to increase out of proportion, or were replaced or taken away, its neighbours would feel the consequences, and a new equilibrium would have to be established. So with species living in a definite place; they are in mutual relation as it were, as the organs are to the body.

“ Nature has a biological correlation as well as an anatomical correlation. The species co-ordinate the needs of life as between themselves. They have a

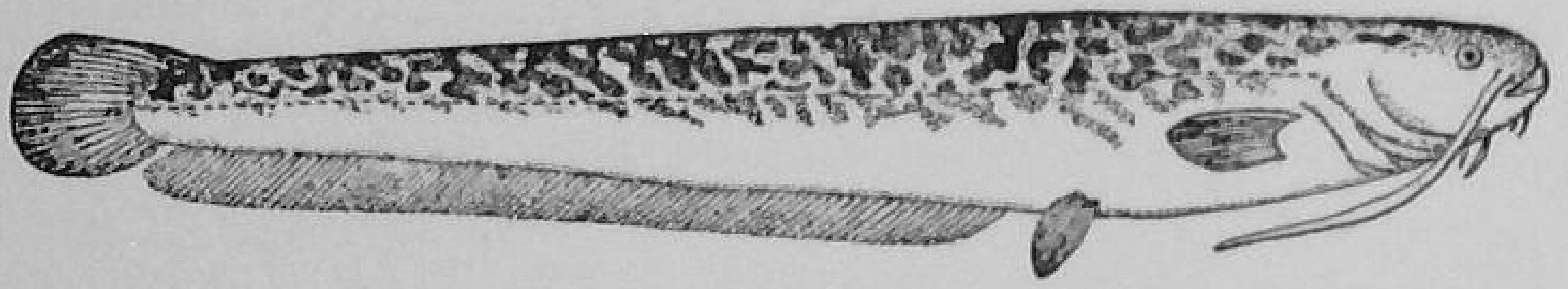

FIG. 43.—The Wels, a giant Catfish. Length sometimes as much as 13 feet.

toleration and a balance of their own. This equilibrium varies in its details, but is maintained as a whole. There is a mutual solidarity. If one attains to too great a domination, or tends to weaken or disappear, its neighbours are affected, and the equilibrium is destroyed. Then Nature intervenes to produce a new equilibrium.

“ It is clear that this equilibrium relates to all the external circumstances which react on the creatures, and upon which they depend, from the temperature of the waters to their composition, the content of substances in solution. But the main consideration is that of food supply. Every species, so far as this is concerned, has its own peculiar characteristics and mode of action; it must have its particular kind of food, and this the water must supply. When it finds this, it prospers, or at any rate, manages to support itself; when it fails

to find it, it declines and its numbers grow less. And all those which live side by side in any given place and together find their subsistence, are bound together, so to speak, by this sort of natural compact, which preserves the equilibrium, giving to each the quota it needs. They are really interdependent, as I said a moment ago; they do not confine themselves to living their own individual lives; they are component parts of an association formed by Nature, and within that association are involved in a correlation which holds them all, without exception, in its restraint. None can remain aloof.

"Now this equilibrium, and especially that of the food supply, depends upon a balance which, in each place, despite variations due to local circumstances, remains practically constant. The arm of the river before us, thanks to its vegetation, the tiny creatures which hide in it, and the insects which fall into its waters, is able to support a certain number of the fish belonging to our species; but it can hold no more because there would not be food enough for them. The table is laid for a definite number of guests; they eat up everything it has to offer, leaving not a scrap behind. The conditions of Nature are such that all her subjects, similarly affected by their need of nutrition, absorb to the very last degree the resources she has to offer. They automatically see to it that the table bears exactly the right amount and no more.

"Now you can see where we made our mistake. We were so keen and so much in a hurry that we never thought of this point. It was only later, by experience and when we could not help realizing our failure, that we started to investigate its cause, and so found out what was wrong. It is not enough to put the fry in the water; it is also essential to see that these little fish, which later will grow into larger fish, find in the water the necessary food. Only so much fry must be put into the water as that water can support. It is not enough

simply to send for foreign species and acclimatize them; we must also make sure that the new-comers do not enter into competition with our native species, which are often worth more to us than the species so introduced. The correct amount of food is on the table, the equilibrium is settled, and when this is so, the new-comers are intruders and are obliged to fight as best they can in order to maintain themselves and live. They are subject to all the changes and chances of the conflict of which they are the cause. Some go under, others flourish. Those which do not become acclimatized, disappear, for they do not find, either as regards quantity or quality, the materials they must have. On

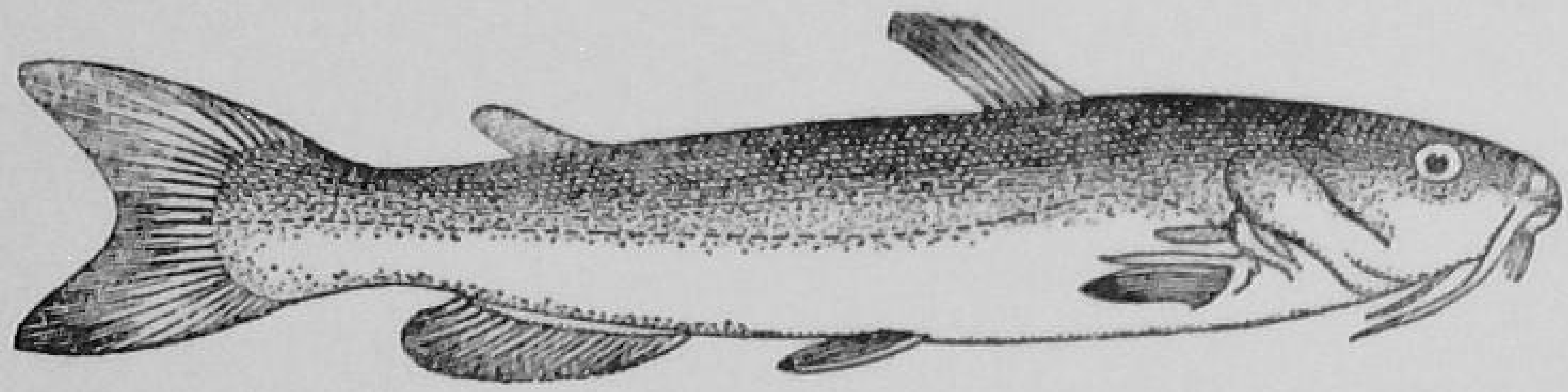

FIG. 44.—Catfish. Usually about a foot long.

the other hand, the sun-perch survives, because its small size sets a limit to its requirements and enables it to find with us all it needs. And as for the catfish, which is more robust than our native fish, it develops and advances more than we care for.

"But for every evil there is a cure, so long as we know its exact cause. The breeders of carp, in their large ponds, now know that their success is proportionate to the nutritive capacity of their waters; this must be improved if the best results are to be obtained. Rivers and streams are more difficult, for in their case it is not easy to ensure a continuous improvement in this respect. Yet, by observing Nature's rules and thanks to the co-ordination she has instituted, we have the power to get results up to a point. Before repopulating by putting in fry, we must first study the degree

and the nature of the nutritive equilibrium, and make our stocking proportionate thereto. Before attempting to acclimatize a foreign species, we must consider its mode of life in its native country, and make a trial before giving it full liberty. Here, as in everything else, the sound method consists in thinking out things in advance, so as to make the best use of the material at our disposal."

CHAPTER XIII

MECHANICS OF RESPIRATION

One of my principal tasks in the management of an aquarium, and it is a matter which always causes me a great deal of concern, is to keep a close watch over the breathing of all my guests, so that no trouble of any kind may arise. Fishes breathe. Like other living beings, they need oxygen. Because they live in water, they can find that oxygen only in the water itself, and there they do indeed find it, absorbing it in a state of solution. Normally water contains in solution the elements of which air is made up, oxygen among them. Some of these elements it takes and absorbs until it can hold no more, whenever both air and water come into contact. The fishes and their neighbours in the water use this dissolved oxygen to breathe. It is essential, therefore, that the degree of solution should be adequately maintained, if the respiratory function is to be properly fulfilled. It is my business to see that the water in my tanks always contains a sufficient proportion of dissolved oxygen, in spite of the continual consumption of it for which my wards are responsible.

There are a number of accepted methods of keeping up this supply, and I choose one or another of them as circumstances suggest. The simplest consists in renewing the water in the tanks either continually or at regular and sufficient intervals. The old water, made unclean by the disappearance of the oxygen consumed, and by various substances formed by the excreta, is replaced by new water, which is free from foul matter and contains dissolved oxygen in the correct proportion. Thus the requirements of respiration are adequately

fulfilled. Many aquariums are thus arranged; the complete, constant renewal of the water without disturbance of the fishes being provided for simply in this manner.

But there is one drawback to such a method. It calls for a large quantity of water and a canalized system of feeding which is not always practicable. So, the main necessity being to provide oxygen at a sufficient rate of solution, use is often made of systems which allow of the maintenance of this proportion at the appropriate degree while controlling the total output. The simplest consists of making the water fall from above, or of forcing it to spread out in a thin sheet, so as to bring it more into contact with the air, extending the surface so as to produce a solution of oxygen in the highest possible proportion. Then the water in the tanks, being so much more richly provided, is better able to satisfy the needs of respiration.

Another and more elaborate process, often employed, is that of an air sprinkler. It is to be seen in well-equipped aquariums. From one corner of each tank there rises a jet of small air bubbles which go up to the surface, losing their oxygen by solution as they do so. This train of bubbles comes out of a pipe, in which the water, issuing in a fine jet under fairly strong pressure, carries along air, stirs it up, pulverizes it in fine bubbles, then passes out into the tank with it. By this means, a small quantity of water is enabled to keep alive and to support a large number of creatures. The final stage in this process consists in injecting air under pressure, so as to replace by new oxygen that which continual respiration is using up all the time, using the same water, which is changed only at infrequent intervals, when the fouling caused by waste products has become too marked.

These various arrangements to ensure adequate normal respiration to a number of creatures shut up in a confined space, and to give them in this respect the same degree of ease that they possess in the state of freedom, is suitable

for the majority of species found in temperate countries, but not those of the more tropical lands. Besides oxygen to breathe, the latter need a constant temperature, a temperature that is high even in winter, usually between 75 and 90 degrees Fahrenheit. Indeed, most of them can get on with a fairly low degree of oxygen, provided that the heat indispensable to them is forthcoming. In order to avoid the expense of canalizing water that has first been warmed, the difficulty is solved satisfactorily by planting an aquatic vegetation in the tanks and letting it grow there, keeping the whole at a sufficient temperature.

Several advantages are thus secured. Branches and foliage, floating in the water, make an ornamental frame, in which the fishes, as they move about in all directions, unite with their environment to give a harmonious representation of natural phenomena. Again, these vegetable growths purify the water on the spot and all the time, so that it need not be renewed, except at intervals sometimes of weeks, sometimes of months. Daylight, acting on the chlorophyll of their green parts, causes it to decompose the carbon dioxide which, produced by the fishes' respiration, gradually dissolves in the water as a waste product. The oxygen, thus set free, is reconditioned and again ready to be breathed. The same oxygen can be used over and over again until the time comes when the greater part of it has been actually incorporated in the substance of the creatures whose life it has supported.

Such a system of managing an aquarium, thanks to the care and constant supervision which it entails, shows how great an importance in life is attached to this act of respiration and the absorption of oxygen which is the essential factor in it. On land, creatures are immediately in contact with it; they have only to draw upon it in its ordinary state, in the form of gas. They gather it at the source, always find it in more than sufficient quantity. The state of affairs in the water is entirely

different. The creatures which live in water only secure it after it has first been dissolved in the medium that surrounds them: they can secure it in no other way. Moreover, in the vertebrates—the fish among them—there are other differences besides those due to the environment. Land vertebrates, in their bodies, have a special apparatus to take the air and its oxygen to the lungs through which they breathe. They have a continuous passage from the nostrils to the lungs for this purpose. Fishes have nothing of the sort. Their respiratory organs, the gills, situated behind the cheeks on the sides of the head, communicate at once with the outer world and the back of the mouth. It is through the latter that they receive the water with its dissolved oxygen. They are obliged to fill the mouth with water in order to breathe, whereas birds and mammals, surrounded by air, can breathe all the air they need through their nostrils, with their mouths closed all the time.

The modest goldfish, in its little globe, will serve as an example. As it moves about, we see it yawning all the time, opening and shutting its mouth continually, as if it were obliged to keep on swallowing. We can also see, behind its cheeks, the golden gill-covers beating gently, rising and falling continually. As we watch closely, it is not difficult to realize that both movements correspond and are successive. There is a beating of the gill-cover for each yawning of the mouth. A little experiment will serve to complete the demonstration. With a pipette, let free near the mouth a small quantity of some harmless, impalpable dust, chalk or something of the sort, or a few drops of some coloured solution. Then you will see several parts of these substances, taken in during the yawning, enter the mouth and come out again beneath the gill-covers. Thus we can determine their passage. The fish takes in water all the time, fills its mouth with it, then makes it pass over the gills and finally ejects

it through the gill-slits. This incessant renewing is the process by which it breathes. By means of these successive operations, it continually distributes fresh water to the respiratory organs whose business it is to absorb oxygen and throw out carbon dioxide.

The goldfish and most of its fellows exhibit these phenomena on a relatively small scale. The yawning is not very extensive; the beating of the gill-covers is relatively weak. Other species, with large heads and an active respiration, show them more clearly. The hog-fish or scorpion-fish (genus *Scorpæna*) are

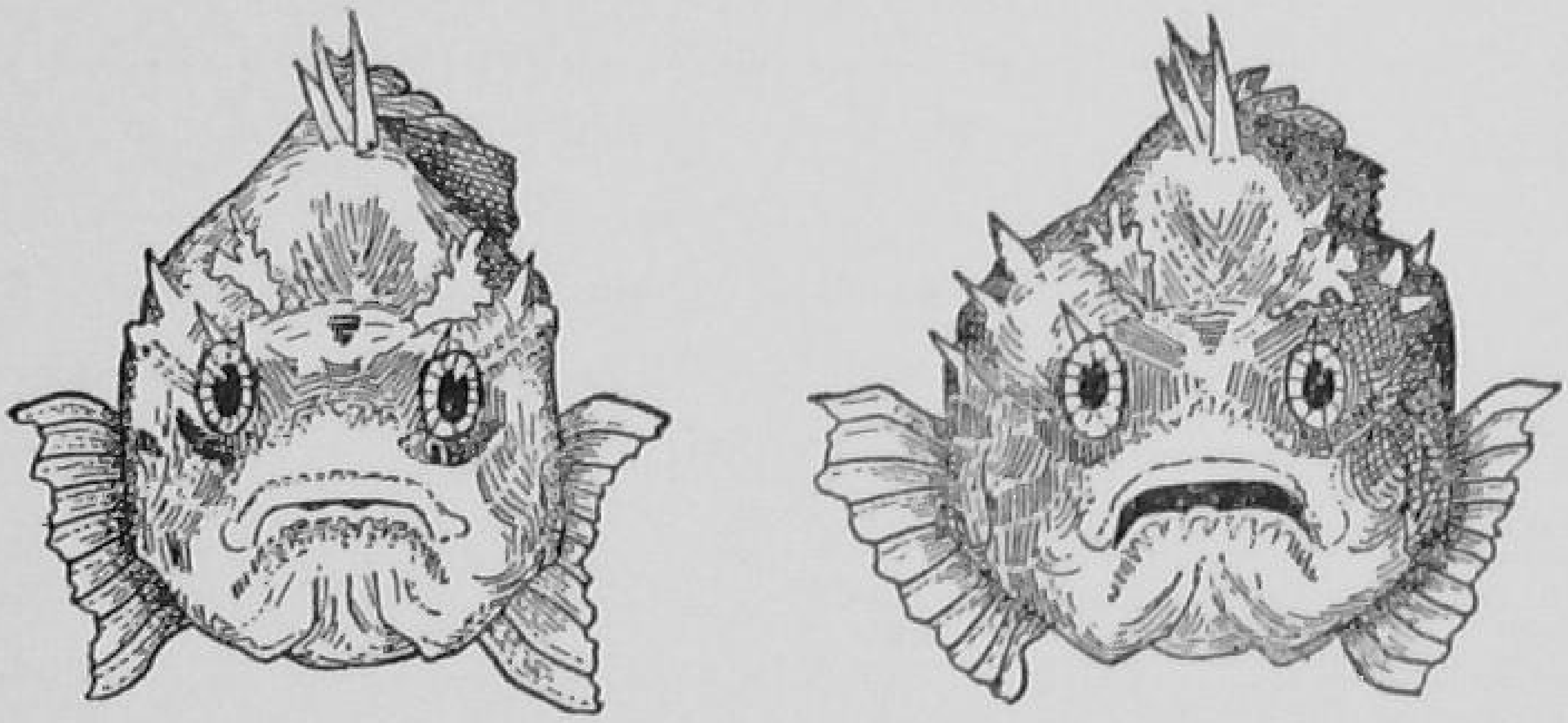

FIG. 45.—Respiratory movements in the Scorpion-fish or Hog-fish. Right, inspiration: the mouth partly open and cheeks expanding. Left, expiration: the mouth closed and cheeks contracting.

such fish. A marine aquarium tank which contains a certain number of them has a good deal to teach us. The hog-fish usually lie stretched out motionless on the bottom. From time to time one of them rises, swims around a while, but soon falls back and resumes its condition of inertia. Their large, heavy heads, bristling with spines, bearing fine strips of skin which wave on their cheeks and under their chins, lighted by two large bulging eyes, are monstrous heads with an evil expression, yet the fish repose with a calmness which the movements of the other fish about them do not appear to disturb in the slightest. Despite their ugly appearance, and the venom of their spines, the

hog-fish seem good-humoured creatures, with no pretentions to frightfulness: their weapons are not to be taken particularly seriously.

Although they stay on the bottom and do not move, the fact that they are alive is clearly manifested by movements of the mouth and gill-covers, and these movements are made still more evident by the large size of the organs which produce them. They perform a regular series of respiratory movements, the various stages of which may easily be followed, since they are confined to the head, the rest of the body remaining still. The creature, as it takes in the water which reaches its gills, plainly reveals an inspiration followed by an expiration, as in the case of land vertebrates. It begins by parting its lips and opening its mouth; then it takes in the water and gradually fills the buccal cavity. Little by little the cheeks expand, the gill-covers swell, while their edges still remain in contact with the body in such a way as to keep closed the gill-chamber which they cover. The head grows larger and broadens. When the cavities of the mouth and of the two gill-chambers are absolutely full, the inspiration ceases and expiration begins. The lips come together again, and the mouth shuts; an inner valvular fold, forming a sort of tongue, makes the closing more complete. The gill-covers sink, their edges rise; the cheeks retract; and the head becomes smaller. The water, thus put under pressure, tries to get out of the cavities in which it is contained, and since it cannot do so by the mouth, which is closed, and the only way left is through the gill-slits which are open, it takes that way and is swept over the gills.

Fish provide us with examples of the mechanical phenomena of respiration, first an inspiration and then an expiration, as do the vertebrates which live in air; but there are a few differences. The fishes have to deal with dense water, not with a light gas like air. The courses followed in the two phenomena are quite

dissimilar. In fishes the water goes from the mouth to the gills, then directly outwards by the gill-slits, without passing again through the mouth. There is no going and coming as there is in the lungs. The respiratory medium surrounds the gills, which are bathed in it, while that of the lungs enters into the lungs and is enveloped by them. The motors are represented here by the muscles and the fore part of the trunk.

These differences, however, only affect the method, not its fundamental basis. In the mechanical phenomena of respiration, the result striven for is a constant renewing of the respiratory medium: the fish succeeds in securing this with the means at its disposal, just as the bird and the mammal do with theirs. Despite differences, there is an essential identity, and in these different cases we are able to arrive at similar conclusions. When I was observing the hog-fish, the number of respiratory movements in normal conditions varied from 18 to 20 per minute, showing a certain regularity which altered, however, when the animal was disturbed. Inspiration lasted three or four times as long as expiration. There was, therefore, a regular control of this mechanism, as elsewhere.

A brief anatomical study will help us further to follow the course which the water takes, and to understand the mechanism as a whole more clearly. In the case of the hog-fish it is only necessary to open the jaws wide and look inside. The broad mouth leads to a large space behind, a vestibule elaborately constructed, with a floor, a roof, and sides. In the middle there is a sort of transverse slit which has corrugated edges. This is the opening of the œsophagus which carries food into the digestive tube, and, because of its corrugation, it is normally closed, opening when the folds are pressed apart by some solid object swallowed as prey. The roof, a smooth dome, coated with mucus which covers the base of

the skull, has, above and in front of this œsophagal opening, two symmetrical projections which can be contracted and dilated. During inspiration they press against the orifice and help to close it. Further forward against the inner edge of the jaw is the valve which, during expiration, completely occludes the lips. As a result of these devices, the hinder mouth may become completely full of water, and send it all in the direction of the gills, without anything being able to enter the digestive tube, or to leave by the mouth.

This, however, is not sufficient. It is also necessary that this water, so enclosed, and in order that nothing may be lost, should thoroughly surround the gills, and bathe them, so providing them with the dissolved oxygen it contains. As a result of the constructional arrangements this is easy. The roof of the mouth, all along its length and in the middle, has large bony, solid sections, which form what is called by anatomists "the hyoidian skeleton", for they are, in fact, the counterpart of the tongue-bones of the higher vertebrates. Situated one behind the other, they form a sort of axial master-beam which serves as a support to other lateral beams, spaced out and separated by intervals like the rafters of a roof. These beams, going up to the top on one side and the other, number five pairs, and anatomists, because of their appearance and their purpose, call them "gill-arches"; and indeed the gills, like large blades made of juxtaposed filaments, are attached at their hinder edge, and the blood, circulating through them, gives them a characteristic bright red hue.

The gill-covers complete the structure. Like movable shutters, able to open or shut at the will of the individual, each of them, placed behind the corresponding cheek, covers the gills and their arches on its own side. When the animal opens them, the space containing the gills opens outwards, like a window of which the shutters are open. When it closes them

the space is closed and connected with the mouth only. Often, when a dead fish is being examined to see if it is fresh, the gill-cover is raised to see if the redness of the gills proves that it is. The gills are then depressed, one on top of another, and it is not possible to perceive their exact connection. In order to do so the mouth must be examined, and then the structure may be seen in its details. It is possible to observe how it works by considering this remarkable structural arrangement, the floor of the mouth, like a window with a grill, the bars of the grill bearing the gills, and behind them, the shutters of the gill-covers opening or shutting this window to the outer world, everything being constructed to act in the water.

The fish, thus equipped, is obliged to behave accordingly and use its equipment. Consequently, its respiratory mechanism necessarily differs from that of the vertebrates nearly related to us, and from our own. On land, breathing usually necessitates the play of the pectoral and abdominal muscles and of the diaphragm, and the elasticity of lungs capable of contraction. The head itself and the nostrils do not move much, if at all. This is by no means the case in fishes, whose gills hang motionless upon the arcaded bars which support them. So far as they are concerned, the process consists of bathing these gills with constantly renewed water which enters by the mouth and comes out by the gill-slits. So, to carry out its work, it employs other means, and has recourse to the muscles situated around the mouth and gill cavities. Respiration, in the fish, produces a characteristic expression. Its muscles as they contract, its details as they move, alter the contours and appearance of the head, and give them a definite expression, connected with the function they are fulfilling. One might almost say that the fish, far from being the cold indifferent creature it is often supposed to be, shows in its face the vital activity by which it is animated.

This expression is not everywhere the same. If, as most frequently happens, it consists of yawnings of the mouth and flappings of the gill-covers, it is manifested elsewhere in many other ways. It varies according to its structure, although the result, the constant renewing of the water, is always sought. In this diversity there is sufficient material for a chapter on physiology, which I can only deal with in a short sketch, based upon my observations in the aquarium.

The gurnards, with thick armoured cheeks the compactness and hardness of which extend to the gill-covers, cannot swell the mouth with water as the scorpion- or hog-fish do; their mask remains immovable, the lips slightly parted, and the mouth half open. But their throat palpitates continually; it expands and contracts alternately, producing motions of inspiration and expiration, because the roof of the mouth rises and falls as it inhales the water and sends it to the gills. Beside them, almost buried in the sandy bottom, the soles, motionless, display only that side of their heads which has the eyes. The gill-cover is behind, quite near. We see it rise and fall to effect the expiration, sometimes partially uncovering the gills, sometimes covering them, following a rhythm of 30 to 35 beats a minute. Inspiration is effected by the corner of the mouth, which is kept open in a kind of permanent gape, the other parts of the lips remaining closed.

The eels, congers and murry, have other peculiarities. In these creatures, the neck swells and collapses alternately, breathing in the water which penetrates through the slightly opened mouth, and breathing it out again through the gill-slits after it has passed over the gills. The wave of swelling begins at the back of the head, extends progressively to the neck and throat, then ceases and begins again with the same rhythm. The fish, lurking in the hollow of a rock or buried in the mud, only allows its head and neck to appear. There

is no sign of movement other than the mechanical, regular, and continuous movements of respiration. In large specimens these movements average from 30 to 32 a minute; in small specimens about 40.

The skate and the shark belong to another category. They are provided with air-holes. In them the main inspiration, instead of being carried on by the mouth, is effected by the two symmetrical special orifices called spiracles or "air-holes" which are found in the head behind the eyes. These openings give direct access to the hinder mouth, and the water from outside penetrates through them, then passes to the gills and flows out by the gill-slits, which here are distinct and not grouped beneath a gill-cover. The principal inspiratory action is carried out through the air-holes, and we notice movement in their neighbourhood. Behind them and the eyes, the upper region of the head, above the large hinder mouth which acts as a respiratory vestibule, rises and falls alternately, so as to enlarge or decrease in height the extent of this space. In certain cases the water is brought from outside through the air-holes, and sent back over the gills. In order to prevent the water from flowing out the same way as it came in, these air-holes are fitted with a small valve like a horizontal flap, which closes them at each expiration. It is interesting to watch a skate breathing as it lies motionless upon the bottom, We see it palpitate at the upper part of the head, as the eels palpitate at the neck or the gurnard at the throat, and as it does so, the flap of the valve opens or closes the hole. The number of inspirations per minute varies, according to individuals, from 40 to 50.

It is not only the fishes, of all the dwellers in our aquarium, who display such signs of respiration. The large crustaceans, crabs, lobsters and rock-lobsters, have their own type of breathing which they exhibit continuously. The rock-lobsters, in their usual position,

are half raised up, bowed upon their long legs, the abdomen bent below, the large antennæ carried upwards, the little antennæ stretched forward like two parallel horns, the bulging eyes sticking out under the big spike which acts as an eyebrow. In this state, with the head almost upright, most of the parts which frame the mouth, the mandibles, and jaws, move and oscillate in a continual to-and-fro motion, like a sort of mumbling. The purpose of these movements is to send a continually fresh supply of water to the gills in a more sheltered position further back. The lobsters, with their huge pincers, the crabs with their stubby bodies, act in the same way, and in the fresh-water tanks, the cray-fish, which have a similar structure, have an identical respiratory action.

Another tank has cuttle-fish swimming about in it. I have already mentioned these molluscs of complex structure, their two methods of swimming, the inner shell which supports their body like a bone, the casting out of their ink. Their usual method of swimming is with the body kept horizontal. Their heads are pushed forward, with large, fine black eyes, partly covered by eyelids bordered with a thread of gold. Their flexible, supple tentacles—one might call their touch caressing, so delicately does the animal use them—hang like probosces, curiously resembling an elephant's head. The oval-shaped body, circled by its marginal fin, is alive with changing hues, iridescence running over the skin like a cloud, sometimes light, sometimes dark and dense. As it swims the creature breathes, and it is possible to follow the movements of its respiration. The water enters through the sides of the opening of the sac which surrounds the body, reaches the gills within the sac, gives them oxygen and then leaves by the median siphon. During inspiration the sides remain open to let the water pass in; the sac fills and enlarges. During expiration, it closes up and empties, and the sides come together

so that there is only one way out for the water, through the siphon.

The poulps or octopuses, behaving in the same way, exhibit the same method but on a larger scale. They have not, like the cuttle-fish, a structure of hard skeletal substance in their bodies, nor have they one around them; there is nothing to limit extension or contraction, so they are able to swell out, as well as to empty themselves, to an extreme degree. Their elastic bodies swell out and collapse like india-rubber bladders. According to circumstances, these bodies change their form and size, sometimes blown-out and almost spherical, sometimes shrivelled and collapsed, so as to find their way into the hollow of a rock.

Other aquatic creatures also have a mechanism of respiration, but one that is less varied and more tranquil; their functional attitudes remain the same for a longer time; the renewing of the water goes on continuously and is not divided, or is less divided, into two opposed phenomena, inspiration and expiration. The clam and the bivalve molluscs which resemble them put out from their shells the two tubes of their siphons, one serving to take the water to the gills in a sheltered position inside, the other to send it out again. Other bivalves, like oysters and mussels, which have no siphons, half-open their shells, and make apertures through which the water can come in and out, so that it is constantly renewed.

In other cases, respiration is managed more simply still. In the absence of inner respiratory organs to which it would be necessary to guide the water, the movements are limited to extruding at intervals the parts which act as gills, then withdrawing them again. The tubicolous worms, so called because they make a shelter for themselves in which to live, behave in this way. The Protules, in their whitish, sinuous tubes, send out, if there is nothing to disturb them, the red plume of filamentous gills which adorns their heads;

they stretch it out in the surrounding water, to fulfil its proper function; and, at the least alarm, fetch it in again hurriedly into their tube. Others, closely related, behave in the same way; they spread out their handsome branchial plume, rolled up in a spiral, inlaid with violet and white, leave it extended in the water, and stay without moving until the moment when, for some reason or other, everything is hastily withdrawn, and nothing is to be seen except the outside of the tube in which the animal lives.

Going still further down the scale, in even more simple creatures like the lower worms, the jelly-fish, and the sea-anemones, there is not even this. The respiratory function, instead of being localized in specially constructed gills, has no specific organ; it is carried out directly over the surface of the body. In this case, since there is no apparatus, the movements proper to its mechanism do not exist, and, since there is no reason for its existence, we see nothing of this mechanism of respiration.

However, this does not prevent its taking place in many aquatic animals, large and small. In it the world of waters has a mode of behaviour, a sort of moving condition, which we hardly ever find in the world of land and air creatures. There are continual plays of expression, which the requirements of respiration render necessary, which compel individuals to carry them out, water being denser to move than air. We have only to look in an aquarium, and there we find the majority of creatures going through these movements, which are more obvious to us than they are in the corresponding animals which breathe in air. The masses of the waters, the vast areas of the sea bed, are peopled by animals continually showing movements which are ordained by the needs of their respiration. Besides movements of locomotion and prehension, they show us also gestures of respiration, more apparent and more varied than we ever find elsewhere.

CHAPTER XIV

TROUT WATERS AND CARP WATERS

One thing follows upon another, and this chapter is a natural sequel to the one that preceded it, since both are concerned with respiration in the water, its methods, and consequences.

But this new question must be asked in a general way if we are to get a clear and complete perspective of it, and, in order to assure this, it is a good idea to look at a map of physical geography, in which the watercourses are shown with the contours of the surrounding land areas. There we see in miniature, and consequently more clearly, things as they actually are. Graphic representation gives life to the whole. We get a comprehensive idea of the places in which the fishes dwell, the way they are formed, their relations one to another, their resemblances and their contrasts. So we grasp immediately the close relationship between the natural conditions of soil and water with that of the life they foster.

The Loire, the great French river, gives us a good example which we may take as a model for other watercourses. Its basin, including the tributaries, covers a total area of over 45,000 square miles. Its course is 615 miles. It begins in the south in the heights of Vivarais, about 5000 feet up, at the foot of Mount Gerbier des Joncs, not far from the Lake of Issarlès. Thence its waters flow directly northwards, crossing the central plateau on one side, and come to the Forez plain. This mountain torrent, narrow, swift, often enclosed by a ravine, seems no more than any other

modest stream, with nothing to distinguish it from its neighbours. But farther on, when it comes down and rolls thereafter through the plain, it extends its bed and becomes the mighty river which traverses one province after another and gathers to itself the waters of about a quarter of France. First, it continues northwards as though to join the Seine; near Orleans, it makes a bend westwards, so preserving its independence, and flows to the Atlantic in the magnificent valley of which it is the central feature. The Val de Loire, hollowed out by it and its tributaries, goes gently down to the ocean like a gigantic incline. And as the river gradually nears the coast, it broadens, becomes a great estuary, and finally loses its identity in the ocean.

Until it reaches the sea, the water preserves its continuity from one end to the other. From estuary to source, apart from local obstacles that have been set up in one place and another, it flows in an uninterrupted stream. Among its fishes, the salmon frequent almost the whole of it, entering the river at its mouth, and going up to spawn in the mountain regions near its source. But this is a particular case, which we find only in migrants. The sedentary and more specialized species are far from having such a capacity for expansion. They settle down and live close together. Instead of populating the whole of the waters, they arrange themselves in different groups, each one occupying its own particular place. The estuary, visited by the tide, has, in its mingled waters, species which live in brackish waters, flounders and mullet. In the fresh waters of the Val de Loire and its tributaries, a number of species are to be found, the carp family giving the characteristic note. Then, higher up stream, where the Loire runs through the mountains, the carp grow fewer; the trout appear and, finally, when the highest regions are reached, remain practically in full possession of the waters.

The carp is found where the Loire flows through the plain and generally at a low altitude; trout where the Loire flows through the mountains and in high altitudes: this is the regular state of affairs, of which we are given a complete example.

These differences are well marked, at least as far as extremes are concerned. At the zones of junction, over areas varying according to locality and time of year, the species mingle, some decreasing and others increasing. The connection is altered only gradually. But when once these zones have been passed in either direction, the distinction becomes clearer and more obvious, and the two habitats, the two categories, are quite definitely marked. Fishermen go to the mountain waters for trout; and for barbel, bream, roach, and bleak to the plain waters, or to lakes at a comparatively low altitude.

The contrast is so closely related to that of climate in the areas themselves that we are inclined to think one depends upon the other. Temperature, it would appear, has a preponderating, if not exclusive, influence; the trout preferring the cold mountain torrents, and the carp the warmer waters of the calm and tranquil river. Now this is true only up to a certain point. The coastal streams of Brittany and Normandy, though they are at no great altitude, have trout in them just as the mountain streams. Indeed, some of them, despite the fact that their waters are very warm during the summer, are considered the best stocked of all, and are most visited by fishermen. There must be another reason, and it is not far to seek if we take into consideration the nature of these waters which the trout frequent. They are always fresh, swift, and continually renewed, practically always clear and limpid. The influence of temperature plays a part, but the principal factor is respiration, and this is affected by changes in temperature, advantageously or otherwise, as the case may be.

If, through their gills, all fishes breathe the oxygen dissolved in the water which surrounds them, their individual requirements differ. Some, which have an active respiration, must have around them a considerable proportion of oxygen. This is the case with the trout. Others, more modest in their demands, are content with a smaller proportion. So it is with the carp family. Now, fresh waters, which differ considerably in their content of dissolved oxygen, vary considerably from place to place and from season to season. Their mixing with the air; their purity; the vegetation on their banks, have obviously a good deal to do with it, but temperature is the most important factor, for according to its height the rate of solution of oxygen changes; the colder the water, the greater its power to dissolve oxygen. Warm water is definitely poor in oxygen. The carp flourish in it; the trout, on the other hand, cannot get on in it at all, unless it is sufficiently stirred by the air: and, in cold water, swift flowing, rich in dissolved oxygen, the trout get on very well and the carp not at all.

Each species has a capacity and faculties of its own. These, being appropriate to its needs, cause it to settle down in those places where it is best able to satisfy those needs. There it settles naturally; there it takes up its abode, is ready to live, and disinclined to leave. The trout do not go down to the rivers of the plain, where the water is warm in summer and flows slowly. Similarly the carp and tench make no attempt to reach the mountain torrents even if they get the chance. Each in its suitable environment realizes in that environment, in the close relation of its constituents, an organic well-being, in which its functions are able to find their due fulfilment and equilibrium. Outside certain limits this equilibrium is broken; the state of well-being disappears, and the organism declines. The living creature can maintain itself and prosper only when it finds around it, in its environment, the

elements which can create this perfect harmony and enable it to endure.

The most important of these elements is the oxygen of respiration, and the quantity in which it is present is determined by the rate at which it is dissolved in the water. Hence aquatic animals, especially those whose respiratory needs are considerable, run the risk of finding themselves in a very awkward position. The water around them must contain the proper proportion of dissolved oxygen. Without it, the water may be of unexampled purity and extremely rich in all kinds of food, but it will not be able to support them. In fresh water, because of variations for which the temperature is responsible, the limit is easily reached, and fish-breeders, whose work is often endangered thereby, must keep continually on the watch.

A carp pond, or a trout pond, which is as satisfactory as can be during the cold season, may see its population depreciate both as regards quality and quantity during the summer, and its owner may occasionally suffer considerable losses. Nothing has been changed; there is still plenty of water and there is nothing wrong with the food supply. But there has not been enough dissolved oxygen, and this deficiency is the cause of the trouble. In winter, the cold water takes more oxygen from the air, and the fish flourish on it. In summer, the temperature goes up and the proportion of oxygen goes down to an unsupportable minimum. The fish are dazed and almost suffocated; they cannot realize the organic well-being to which they are accustomed. Their power of resistance lessens. Diseases, the germs of which are found in all water, take hold of them more easily. Usually, the fish-breeders are warned of the existence of such an asphyxiating state by the growth of a filamentous fungus on their fish. It is grouped in sticky, fluffy masses. They must then strike at

the cause of it, improve the condition of their ponds, and fill their ponds or tanks with more life-giving waters. Fish-breeding is like any other kind of breeding in that it has rules of hygiene of its own. The cattle-breeder and the poultry-farmer must have the area and cubic space to provide plenty of air. The fish-breeder must have them too, but in his case the air, or rather, its oxygen, is dissolved in water, and he must use the water as an intermediary.

In the sea there is not so much variation. There are variations in the degree of dissolved oxygen and in the respiratory needs of the animals which live in the sea, but there is not so much difference between extremes. This vast medium is more uniform, the more so because the rate of solubility of oxygen is not quite so high in it as in rivers and lakes, because sea water contains salts in solution. The contrast is especially noticeable near the shore, where the fresh water coming in, the waves beating upon the rocks and whipping the air as they fall back in foam, often tend to increase the amount of dissolved oxygen. Taken as a whole, sea water is not so rich as most fresh water, and it is richer near the shore than out at sea or deep down. From the abysses of the ocean to the peaks of mountains, from the deep salt waters to the fresh waters of the mountain torrents, the respiratory environment is always becoming better, so far as its capacity for oxygen is concerned.

This brings us again to the trout, and its relatives in the family of Salmonids, whose requirements in oxygen are about the greatest among fishes. Respiratory activity leads to an oxidation in the centre of the living creature, an oxidizing combination with the substance of the organs. The oxygen, taken from the environment by the skin, the lungs and the gills, carried along by the circulation, diffused into ever smaller particles, finally reaches the tiniest components of the organism, and effects its combinations. Physi-

ologists call this "respiratory combustion", and it is a good name because, like ordinary combustion, the action consists in an expenditure of chemical energy in which oxygen plays the principal part. One of its main ends is a setting free of carbon-dioxide.

Every act of combustion, every oxidization, is accompanied by the production of heat, though the degree varies. This is sometimes immediately counteracted, so that it is hardly noticeable, sometimes set free, at least in part, and there are evident traces of it. The caloric energy thus engendered is essential to the maintenance of life. The other vital activities depend upon it, and can only manifest themselves, as it were, on its terms. If it goes beyond the limits of "organic well-being", or if it falls below them, life hesitates and there is a breakdown. Among fishes, the trout and similar species occupy a privileged position. Endowed with a particular intensity of respiratory oxidation, they can resist low temperatures almost to freezing point, continue living in waters affected by such temperatures, and carry on the majority of their vital activities in them. In this fact, probably, we find the reason for the special characteristics which fit them among fresh-water species for their peculiar mode of life.

They have a high coefficient of respiration, which means that, in a given time, a definite weight of their flesh absorbs a greater proportion of oxygen than in the case of fishes less well equipped. Consequently, the result of the intensity of their oxidizing processes being the production of a greater caloric energy, their organism continues to be able to work, despite the low temperature of the environment. In the middle of winter, in mountain streams whose water is only a few degrees above freezing point, the trout come and go and breed, their eggs hatch, and their fry develop without any difficulty.

The carp are in a very different position. Their

coefficient of respiration, about half that of the trout, makes them extremely sensitive to low temperatures, and this weakness of internal oxidization prevents them from resisting such extremes. In autumn, when the water goes down to about 50 degrees Fahrenheit, most of them cease to feed. Even if they absorbed nourishment, they would not be able to digest it, for the digestive juices and their diastases would not be able to function. Yet at the same temperature the trout are both agile and voracious. When the temperature is still lower, the fish seeks a shelter or falls to the bottom in a condition of lethargy. It hibernates. Its life is suspended. It will return later, in the spring, when the waters are warmer again. Then, with the progressive rise in temperature, life will begin again; the fish will get up, begin to look for food, and carry on its vital activities. Hibernation is over.

We find an interesting contrast in fish-breeding establishments. The trout ponds are as animated as ever in winter. It is the spawning time, when fish are chosen to breed from, a time for artificial fecundation. The fish which are not yet ready to spawn are fed and continue to grow. Though the weather is cold, they go on seeking prey, and they swallow it greedily enough, though digestion, at these low temperatures, is not always complete. Carp ponds, on the other hand, have a very different story to tell. In the largest of them, the winter is the fishing season, the time when the fish are sent to market and eaten; but in the smaller ones, containing the smaller specimens, it is a period of rest. The carp do not feed and do not move. During the winter months, there is no sign of life in them. Many carp raisers have special narrow, deep tanks, filled with cold water continually renewed, in which the carp, taken out of the ponds, are placed to pass safely through the winter season. Their lethargy permits of their being

handled in this way; inert, and heaped up almost one on top of the other, they can spend whole months without moving or eating.

A hibernation of this sort, which is accompanied by a partial stoppage of vital phenomena, has certain definite results. The trout grows in mid-winter, though not very much, but the carp does not grow at all. Its growth stops with the first frost of autumn, and does not begin again until the spring. For four, five, even six months, varying according to year and locality, the carp remains stationary, not growing or becoming any bigger, even losing slightly. The real growth, the increase in weight and size, takes place only during the warm summer months, and the higher the temperature of the water, the better, quicker, and more satisfactory it is. This growth is not regular; it has its ups and downs; it is not like that of land creatures, such as we see it in stables and poultry farms, where growth goes on regularly and with continuity. The carp give up to it only a part of their existence; it is subordinate to the seasons. So we understand the reason why carp breeders count the age of their stock by summers and not by years. The carp is a product of summer, like the fruit of our trees and the grain of our harvests. It lives and grows under the beneficent influence of a favourable seasonal temperature.

This thermic influence of the environment upon the living world of the waters is direct and considerable. Its result is an adding to the caloric energy of the combustion involved in respiration; and is consequently always of great importance. In spite of all divergences in the constitution and needs of the creature, and in external circumstances, it provides the organism with the means of accomplishing the functions which enable it to survive. It does so all the more because it is, in this respect, in a more precarious and dependent position.

The fact that the trout have a high respiratory quotient, that they consume a greater proportion of oxygen, produce within themselves heat enough to enable them to resist a certain drop in the temperature, does not mean very much. They produce just enough to reach this result and no more. Consequently, what follows is even truer of other aquatic animals which are not so well equipped. None has really any animal heat of its own; all are subject, fundamentally and completely, to the thermic influence of their environment. The oxidization which goes on in them, their respiratory combustion, is too weak to free them from this control and enable them to ignore it.

This is not the case with the higher vertebrates on land, the birds and mammals which have a constant temperature. Not only does their organism engender in itself the caloric energy needed for its activities; it produces enough to have some to give away, to enable itself to become a source of heat. Instead of being subject to the action of its environment, the air which surrounds it; instead of getting warmer or colder with that environment, it is independent of it. Moreover, this production of heat goes on in such a way as to maintain a constant degree of temperature within the creature, and to maintain it despite all external changes. Whatever the season, or place, or change in the weather, their body in its normal state retains a definite degree of heat, which either does not vary, or changes very little, and controls the action of the various functions. The organic economy is made to work at such a temperature and not at any other. In this thermal constancy, then, it finds its actions controlled, and it develops a corresponding line of behaviour which is not found in cold-blooded living beings.

The latter, and the fishes among them, have neither a constant degree of temperature nor the regulation

of functional action which follows from it. They are animals of variable temperature. The interior temperature produced in them rises only slightly above the temperature outside. The case of the tunny and the large scombers, whose massive bodies become considerably warmer when they are swimming, is an exception. Usually the temperature of the creature depends upon that of the water, is modelled upon it, varies when it varies, and the organic functions are arranged in such a way as to work at different temperatures. There appears to be in every case a certain optimum at which the organic well-being is complete. Below and above it, the functions are restricted, deviate and even stop, and the organic machine finds itself incapacitated in its work of living. In the carp, the capacity to move freely begins when the water is at a temperature of about 50 degrees; the capacity to feed and digest at about 59, to breed at about 68; and above 77 the vitality again begins to be affected but in the opposite direction. This is a dependence from which the higher vertebrates are very largely exempt.

Fishes show us, better than land animals, the essential quality of every living body. The creature, in fact, is really an automaton which has within itself, fashioned and built up by its own efforts from the embryonic stage, all the wheels of its vital mechanism. But it is incapable of putting those wheels into action by itself alone. There must always be something to start it, to keep it on the track. These impulses come to it from its environment, from the matter and energy of which that environment is made up. It is placed under their control and can only act in accordance with that control.

None the less, it is constructed in order to receive them, even to solicit them. It is an automaton possessed of senses. It has apparatus, organs of sense, which enable it to perceive most of the vibrations and

radiations with which the environment is ceaselessly pervaded. It is not a simple mechanism, indifferent and inert. Its substance quivers with continual animation, always on the alert, which continually stirs up and brings together forces and elements within it. It feels, and it acts as its sensations dictate.

CHAPTER XV

THE FEELERS OF THE BARBED MULLET

The ancient Romans were exceedingly fond of fish. In this way they made up for the frugality of their ordinary diet which, for the most part, consisted of bread, cooked pastry, vegetables, fruit, and milk. Like all southern peoples, they did not eat much meat, keeping it for great occasions, religious feasts, and banquets. Fish gave their vegetarian menu a touch of delicacy which they appreciated and sought, as the inhabitants of Mediterranean towns still do. In the year 701 of the Roman era, that is about half a century before the birth of Christ, Titus Annius Papianus Milo, Sulla's son-in-law, was accused of having caused a riot accompanied by bloodshed. He entrusted his defence to his friend Cicero; but the latter, alarmed by the posting of armed soldiers round the Forum on the day of the trial by Pompey's orders, did not dare to plead the cause as cogently as he might have done. Milo was exiled and fled to Marseilles. Later, Cicero, having made out his case in full—the famous *Oratio pro Milone*—sent a copy of it to the exile. After reading it, Milo said: " It is a pity that my lawyer never made this excellent speech, for I should assuredly have been acquitted. But, then, I should never have come to live at Marseilles, where I have such excellent fish to eat every day."

Later, under the emperors after the time of Cicero and his client, wealth poured down on Rome, and the art of cooking became more luxurious. The simple dishes of earlier days developed into something more elaborate. Fresh supplies of sea fish were continually

being brought to the markets; efforts were even made to keep the fish alive in large tubs. The wealthy, at their villas near the sea, had cleverly contrived tanks of vast extent, in which were kept the fish that could live in captivity, murry and other eels, sea bream, and others. The most highly esteemed was the red mullet, whose scientific name *Mullus* comes from the adjective *mulleus*, meaning red in colour. What men liked about it was not only the goodness and succulence of the flesh, of which connoisseurs of our own time also think highly, but the variety and splendour of its colours, especially at the moment of dying.

In special banquets, a vessel full of sea water in which mullet just taken from the tank were swimming about, was placed on the table before the guests, resting idly on their cushions. Then the water was taken away, or perhaps replaced by a little milk, so that the fish died of suffocation by slow degrees. During the few minutes of their struggles, as they leaped and tossed about, the empurpled hues of their bodies brightened or went dull, disappeared on one side or grew stronger on another, glittered with every kind of iridescence and sparkled with the play of the light. Those present began by amusing themselves with this feast for the eyes. When the mullet were dead, inert and pale, they were sent to the kitchen, whence they were brought back a few moments later, carefully cooked and cleverly served, ready to delight the palate after having charmed the eye.

To us this seems an outrageous gastronomic extravagance. Like the ancient Romans we take pleasure in a good table and good service, but we do not try to combine sensations of so divergent a nature. We prefer to take things individually, the better to appreciate them. We have our fishes to look at, of which we think highly because of the beauty of their colouring; and we have fish to eat, in which we only desire delicacy of flesh. We enjoy the mullet when they

are cooked and served, and we do not ask to regale ourselves in addition with the spectacle of their agony, no matter how brilliant the colour-effects it may produce.

However, the spectacle can still be seen. It occurs every time the fish is caught, as it is taken out of the net and dies. The fishermen turn it to their advantage; they scale the mullet to brighten up their scarlet colouring, and to make them more attractive when they are offered for sale. I myself have seen it several times when I have been catching this fish; and, when I have seen and thought about it, I have understood the attraction it had for those Romans of the empire, whose luxury and sensuality have never been surpassed and seldom equalled.

In the morning when the nets put out the night before near the rocks of the coast are taken up, mullet, still alive and full of vigour, are often found in them, especially in the Mediterranean. It is easy to pick out a few and put them aside for examination, laying them on a white cloth or a light-coloured dish. They die there, as they died on the table of the ancient Romans; they leap about in their struggles, periods of quietness alternating with their leapings; until at last they die, and then they show the changes of colour which made them famous.

They have two colouring substances, or two pigments, in their skin, one a brownish grey that is fairly dark, the other a pure and brilliant pink. Both are disseminated in fine granules throughout cellular elements which are capable, according to the stimulation they receive, of expansion or contraction. According to the phases of these expansions or contractions, the hues are altered, not by changing shade but by changing vigour. The purple tones can vary from the brightest carmine to the palest rose, almost to white. Again, the brown tones may go down through every shade of grey until they almost fade out completely. These

coloured cells which contain pigments called "chromatophores" or "colour-bearers" may be found in the skin of most fishes, but they seldom display, as they do in the mullet, such an intensity of shade and such a rapid change.

These modifications are noticeable in normal life. On specimens kept in an aquarium we may see patches appear, persist for a moment, then fade out or disappear, or perhaps move elsewhere. The sides of the head redden like the cheeks; the white bellies become scarlet; the brown backs grow pale and turn a pearly grey. Here we have transformations of colour which become stronger, more numerous, more intense during the frantic struggles of the fish when it is taken from its element. Then they vary at different times and in individuals. In some, the whole belly becomes a bright red, leaving only a narrow band of palest rose in the middle. In others, we find purple bronze patches, sometimes many in number and close together; sometimes broad and spaced out. These patches appear, spread, gradually grow stronger, then weaken and fade away. As death approaches, these bright hues grow dim and become mixed; the pink becomes leaden in places; and, when the end has come and the fish is motionless, the body takes on its last vermilion, a shade which it will keep thereafter, from which it gets its name.

When once we have seen this extremely interesting death, we can understand the attraction such a sight had for the Romans. What escapes us today, or what seems useless, had an interest and a meaning to them. We must bear in mind, remembering their stories, or after visiting what is left of their houses, say at Pompeii, the extreme importance they attached to complete satisfaction of the senses, the most vulgar as well as the most delicate. Brutal and refined, both to excess; that is what most of them were. Their wealth, their might, their domination, enabled them to realize their

desires. At a formal banquet, the host sought not only to offer a fine selection of succulent and exquisite dishes; he endeavoured, further, to bestow upon his guests every kind of distraction and pleasure. The meals lasted for days. They were interrupted by intervals, speeches, acrobatic displays, plays, songs, dances, sports, and burlesques. All the senses received satisfaction until complete satiation was attained.

One such interlude was the contemplation of the dying mullet. We can picture to ourselves the scene in those halls, beautifully decorated as at Pompeii, where elegance and wealth each tried to outstrip the other, all gay, all bright, with the sound of a melody played on flutes by girl musicians wearing the lightest of veils, as they are depicted on ceilings that have escaped destruction. We can picture the heads of the guests bent above the vessel in which the mullet were expiring. The fishes twisted and turned, like the bodies of gladiators wounded in the battles of the circus. The purple patches appeared, extended, like bleeding wounds. The fresh odour of the rocky shores which they exhaled pleased the sense of smell, excited appetite. And the guests found the same delicious odour in the sauce which, served round the mullet on their return from the kitchen, had been made of their livers pounded with aromatic herbs.

Of these elaborate repasts of former times nothing but a relic of the mode of preparation has remained to us. But in the neighbourhood of the Mediterranean, in our own day, epicures, when they can secure newly caught and absolutely fresh mullet, give instructions for them to be cooked without being either scaled or cleaned, and they will consider only one method of cooking the fish—grilling for a short time over a wood fire. When the fish is finally placed in front of them, they remove the scales, which come away without any difficulty, separate the flesh and put it aside, and take out the liver and intestines. These they pound up

in oil and condiments, and make of them a sauce which they use to accompany, or rather to enhance, the enjoyment of the flesh. "The mullet is the sea woodcock," they say, pointing out, however, that one has to wait several days before the woodcock is ready for eating, whereas the mullet should be eaten as fresh as possible. When they are prepared in this way, say these epicures, they are equal to the very finest fish. Indeed, some say they are the very best.

This apologia of taste, so far as the mullet are concerned, is not out of place. They are often called the Bearded Mullet because of the two feelers they have under their chins like a beard. This distinguishes them from the gurnards and other fishes of bright red hue which have no such whiskers. These appendages are organs of taste.

The bearded mullet may also be distinguished by the shape of their heads, as well as by their colour and the feelers on their chins. The long sloping forehead forms a continuous curve with the back, then passes downwards to the snout, which prolongs it like a broad, blunt nose. This head, which reminds us of that of the red mullet, has the mouth set low down, almost ventral. The feelers are attached below it near the middle.

Their genus, called *Mullus* since the time of Linnæus, who was the first to give it that name in memory of the fondness of the Romans for it, has, in European waters, only one principal species, comprising several types according to habitat, size, and doubtless sex. The most abundant, and that most frequently caught, is the common or bearded mullet (*Mullus barbatus*, Linnæus) which is found over the muddy bottom of the open sea, where it is taken by draw-nets. It is of uniform hue, carmine on the back, rosy on the sides and beneath the belly; its length seldom exceeds 7¾ inches.

The others, less often met with, though still fairly common, live in shallower water near the coast, or in certain pools in which the sea water is very pure; they

like the sandy shores and the small gravel which stretch out below rocky cliffs. These fish have more varied colours, and are often larger, sometimes reaching as much as 8½ to 12 inches in length. The back has brown patches besides its purple pigmentation, and the top of each side is traversed by a brownish band which extends from the eye to the beginning of the tail and is connected with three or four parallel bands of a bright golden colour. Varying according to locality, sometimes according to individuals, sometimes even from moment to moment, the brown pigment is dominant or becomes less pronounced, sometimes fading completely away. In the first case, the type of which is common in the southern Mediterranean (and known as *Mullus fuscatus*, the red mullet), the brownish tints are associated with purple and the two shades form a somewhat sombre livery. In the second, the surmullet (*Mullus surmuletus*, Linnæus), which is to be found both on the Mediterranean coasts and on the Atlantic as far as the Gulf of Gascony, but only rarely further north, the red and pink shades, the golden bands upon the sides, are more definite and brilliant. The colour is more striking, brighter, and more pleasantly shaded. It is exhibited by the most highly esteemed mullet, those which are usually called *Surmullets* in English and French, *Salmonete* in Spanish, and *Triglia* in Italian.

These shore mullet, both brown and rose coloured, are not difficult to catch with fixed nets, and can be kept alive in aquaria. There they may be seen, stretched upon the bottom, where they raise themselves upon their pelvic and anal fins. They are often motionless and, because of the slope of the head and the height of the forehead, the body, girt by its belts of gold, seems humped. Occasionally they rise and move forward, but they do not swim for long, soon sinking and reassuming the position of repose which is customary to them. The only sign of life they show is, at intervals which are often long, the sudden straightening of the

two feelers which are attached beneath the tip of their snout, under the mouth. Like long, conical wands, light-coloured, almost white, these, previously lying beneath the throat and laid back against it, rise up, project to one side, or forward, feel around them with their flexible points as though in search of something, then fold up again and resume their place until the next time they are thrust forward.

To see them thus, one can hardly think of them as anything but organs of touch. They might be two mobile fingers, supple and prying, situated on the chin and able to move in all directions. This resemblance to fingers, this situation beneath the lips, is the reason why, in descriptions of them, they are often described as "tactile whiskers". But the impression changes when we see what takes place when we feed the mullet. The food, fragments of fresh fish, crustaceans, or molluscs, is put in at the top of the tank and has to sink to reach the fish. But before it gets to them, zigzagging down through the water, and as soon as the first tiny pieces begin to reach the bottom, the mullet, though they may not have been touched, rise, move around, and swim about ready to snap them up. Their feelers rise up, stick out, then fall back and rise again, moving feverishly, although there has not yet been any contact between them and the falling fragments.

It is obvious that some sensation more delicate than that of touch has been aroused, a sensation capable of perceiving the presence of prey at a distance; and that, besides touch, the feelers possess another sensitive capacity, one that is more delicate and more penetrating. In the face of this examination we are compelled to take another line of thought. There can no longer be any question of a functional comparison with fingers concerned only with touch. As regards sensation, the resemblance becomes that to a double or branched tongue, particularly susceptible of taste. The fish extends its two feelers in the water to perceive taste

emanations there, as it might do if it possessed a forked tongue which it could dip in the liquid surrounding it. More than all else, these feelers are organs of taste.

A study of them under the microscope confirms this comparison, as may be seen from Figs. 46 and 47.

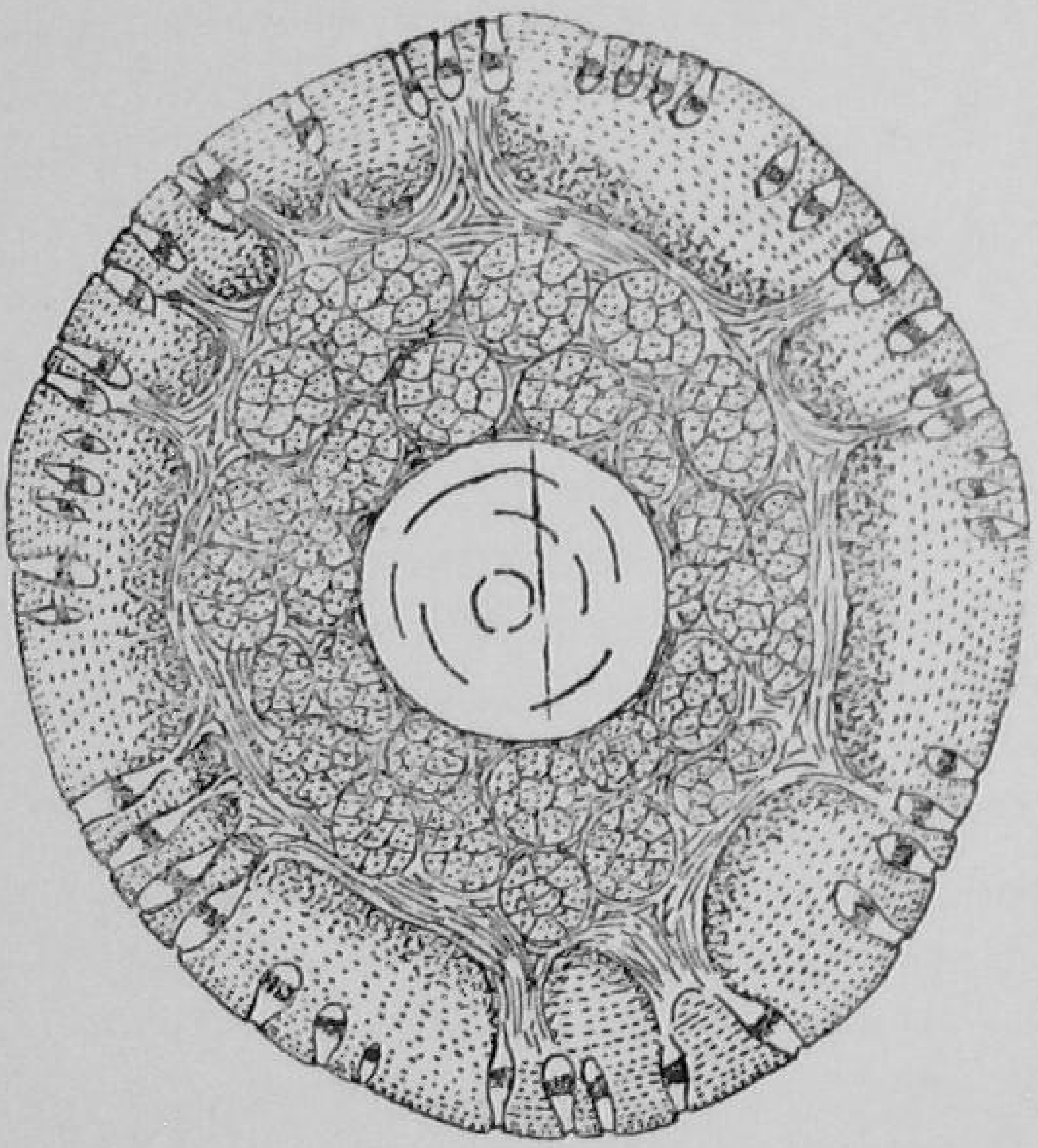

FIG. 46.—Simplified and enlarged view of a transverse section of the barbel of a Bearded Mullet showing (centre) the skeletal axis with a surrounding envelope of muscular tissue; nearer the exterior the thick skin with taste-buds, oval in shape. Magnified 40 times.

The surface in its outer layers, in direct contact with the water, contains tiny swellings called "taste papillæ". There are many of them, and they are like those which, equally small and numerous, are found on the surface of real tongues capable of taste, our own, for example. This identity of structure serves to indicate an identity of function, and of the work they accomplish. The mullet tastes with its feelers; it uses them for tasting rather than for

touching. When it searches with them in the sand, or underneath the pebbles, it perceives taste rather than tactile impressions; it acts like a dog ferreting about, and is governed by smell. It follows a scent. It has its own field of taste, and other fishes have it also.

The case of the mullet is not isolated. Its feelers are whiskers of a peculiar kind, but they are still whiskers.

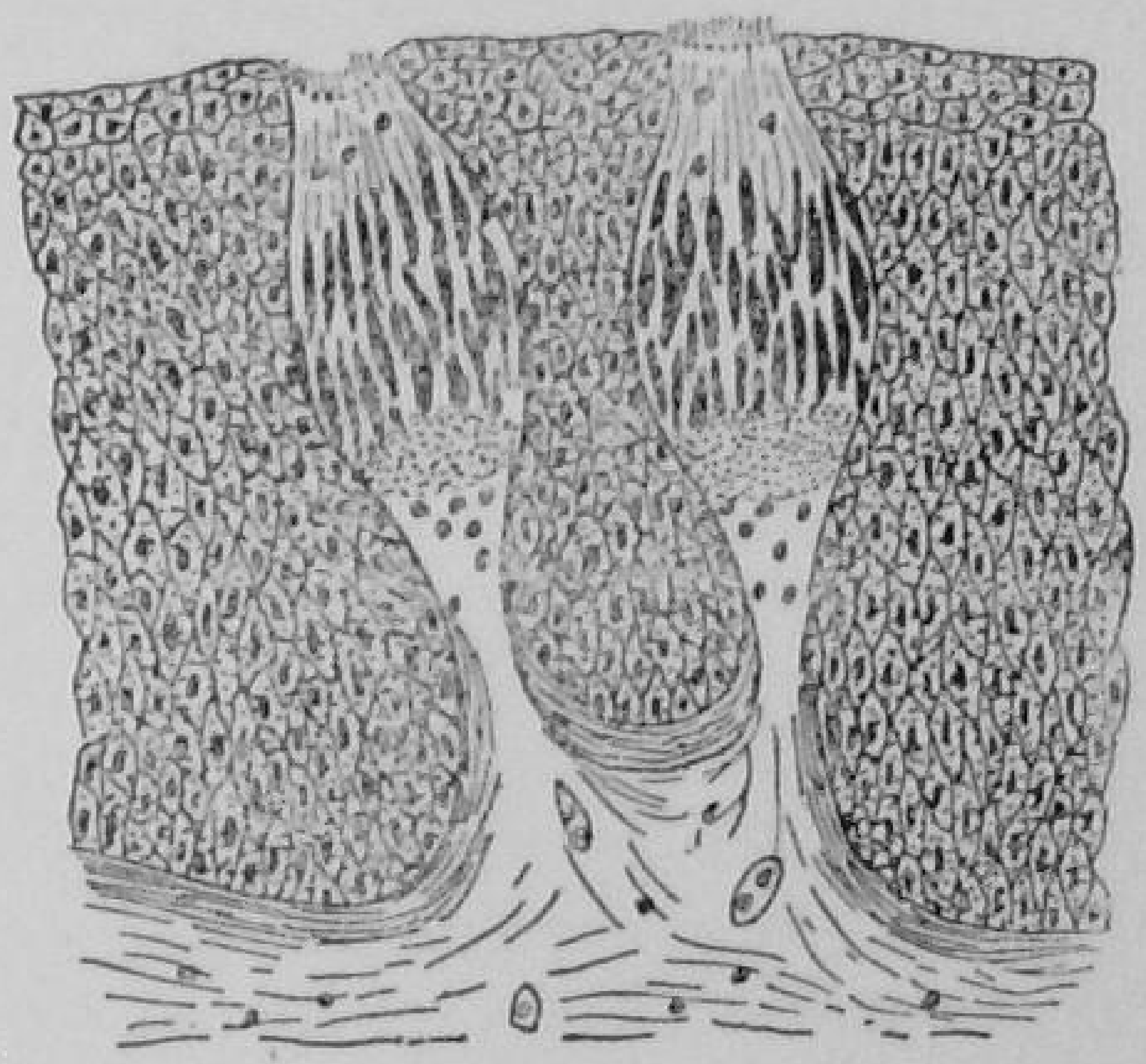

FIG. 47.—Simplified and enlarged section of two taste-buds in the Bearded Mullet showing the long, closely-packed cells ending in tiny superficial filaments. These two buds, like those in the higher vertebrates, are encased in a thick skin composed of polyhedral cells. Magnified 250 times.

Many other fishes have them on their lips, round their mouths, and those too have taste-buds in their superficial layers. Those fishes, still more numerous, which have not these appendages, are not, however, without sensitive organs, for they have them in the walls of the lips, the cheeks, the forehead, and the nasal cavity. I have used the mullet as an example and amodel because of the activity of its mobile feelers, which accentuates the effect produced by their use as a sense organ, but this phenomenon, this sensitivity, this perception of

tasting substances, is a regular characteristic of fishes. These creatures, surrounded by the water, their accustomed environment, regularly taste it. Bathed by it, they perceive its various gustatory qualities, qualities bestowed upon it by substances in solution, just as land animals perceive in the air emanations of odours which are mingled with it.

This more definite characteristic of the mullet is due to the nature of its feelers. These appendages belong to a different category from that of the whiskers of most fish, and consequently I have preferred to call them by the name I have chosen because it better accords with their method of use. Usually the whiskers consist of outgrowths of skin which appear on the lips or neighbouring parts. They are drawn out like cylindrical or slightly conical rods. They are embedded in fixed bases, and their capacity for movement, which is purely passive, is due to their flexibility. This is not true of the mullet. Here, and this peculiar feature is characteristic of the family, they are formed by two detached rays of the gill-covering membrane which surrounds the gill cavity below. Isolated from it, they become free and independent whilst keeping their articulation with the front part of the lower jaw. Thus jointed, they have a fundamental capacity for movement which the animal does not fail to make use of and, in some measure, they simulate little limbs, capable of movement, of being raised or lowered at the will of the individual.

These detached rays, an unusual feature, appear when the mullet is still a fry measuring not more than an inch and a half in length. At this period of its existence, when it is scarcely a few months old, the mullet has very little resemblance to what it will be later, when it has grown larger and stronger. Its body is thin and elongated, and has no red pigment; its colours, on the contrary, are blue and white. Instead of staying on the bottom, it swims without resting, forming a part of the

plankton and, like its fellows, feeds upon tiny floating creatures. This period is one of active dispersion and continual raiding in all directions. Then, gradually growing longer and thicker, it becomes heavier and finds it harder to remain afloat in the water. Its feelers become distinct and more formed. Little by little, it allows itself to sink, gives up the surface zones and goes to deep water, settles down on the bottom. It loses its blue coloration, and the red pigment appears. The final, adult stage begins to set in. The frail, minute fry, which used to be blue and white, dashing about the surface waters, has become a fish of sedentary habit, brown and purple in hue, established on the bottom, a delver in the mud, a stirrer up of the sand, all as a result of the gustatory feelers it has underneath its short chin.

This strange episode is, however, only an instance of a story which could be told of all creatures that live in the waters. They are surrounded by taste-impulses as land animals are surrounded by scents. Their aquatic environment is a world of taste as our environment is a world of smell. The water holds in solution or in suspension substances which can produce sensations of taste as the air has mixtures of gases which also can be perceived by the sense of smell. These two ways of receiving sense impressions are equivalent and result in an identity of response.

In order to understand the situation properly, we must first consider what happens in ourselves and in the animals which, like us, live in the air. We have two kinds of sensation, smell and taste, and two organs which are concerned with them, the nose and mouth. The nasal cavities receive odorous emanations directly from the outside world, their origin often being remote. They accept these sensations in a gaseous state, mingled with the air we breathe; the sensation is one arising at a distance, a *telæsthesia*.

The mouth is different. The tongue has taste-buds

and can only do its work when brought into immediate contact with substances either themselves liquid or dissolved in a liquid. Taste, therefore, is chiefly the business of the mouth.

In the land world, taste is a closed sense, whereas smell is an open sense. They are different in two respects, first as regards the condition of the substances which affect them, gaseous on the one hand and liquid on the other, and secondly, by the nature of the impression conveyed, which is from a distance in the first instance, and limited in the second. We are surrounded by odours, varying in nature and intensity, brought to us by the air in which we live; but to taste, to perceive savours, the conditions of life on land compel us to feel sensation only in the mouth, on the tongue, by direct contact with the object. Taste works only inside the organism. We smell things at a distance, and taste within ourselves.

The conditions of aquatic life are different; in it creatures are surrounded, not by air, but by water. The substances which cause the impression cannot reach them except in a dissolved state or as liquids; they cannot be gaseous. The sensation they experience is the equivalent of our taste. But, in the world of waters, it loses its limited, internal character and becomes external, like our sense of smell. The fish need not receive substances that taste in its mouth, on its tongue. They are disseminated in the surrounding water as odours are in the air round us. Taste, in the fish, is from an external, not an internal, source. It is perceived as the sense of smell is in us.

The double sensitiveness of land animals, taste and smell, is united in aquatic animals. Theirs is a sense of taste which behaves like a sense of smell. The creature tastes at a distance. The taste-buds, scattered about its whiskers, lips, and cheeks, placed in contact with the surrounding liquid and the taste-evoking elements it contains, receive from outside the materials which pro-

duce the sensation; they have not to wait until they are brought within the mouth. Organs so situated in land animals would have no faculty of taste; no such sensation would be produced in them. In animals living in the water, on the other hand, they are situated where they are most useful. They receive emanations from outside, as the nasal cavities receive theirs.

This mixed sense of fishes and aquatic creatures, essentially gustatory, since it involves an impression caused by liquids or substances in solution, but olfactory in behaviour, since it gains its impressions directly from outside, is very common in them. They are able to appreciate, through taste, the varying qualities of the environment in which they live, and to become aware of the presence of prey or of enemies some distance away. Animals excrete substances either through the skin or in other ways. On land, many of them give out odours by which they manifest their existence and their situation. In the water, these odours are savours which are received, incorporated and passed on by the environment. They can be perceived at a distance.

When dealing with the land world, the word "flair" is sometimes used to denote the quality which, by odour, urges and directs towards a desired aim. This flair is olfactory. By it a hunting dog finds its way to the game. It seeks those places where the sensation of smell is progressively stronger and stronger, and so it finds its quarry. So, in aquatic animals, there is a gustatory flair. Taste emanations, exuded by a body in the water, gradually become disseminated and get weaker as they get further away. The creature which perceives them has only to behave like the dog, and move gradually in the direction where the sensations are more intense, and so reach the body from which the exudation proceeds. The dog is guided by its nose; our aquatic animal is guided by the lips, whiskers, snout, nostrils, by all those parts of the body which are

provided with taste-buds. Although it is of another sort, its flair serves, none the less, the same purpose, and it is capable of considerable intensity. For several yards, hundreds of yards sometimes, many fishes, perceiving tastes, go after the sensations which come and affect them from afar.

Fishermen base a good many of their customs on the existence and capacity of this olfactory flair, both in fishing with the line, bow-net fishing, and when using other tackle. The fish is attracted by a bait. It perceives it from afar and comes nearer and nearer until in the end it is caught. When the fisherman is particularly anxious for a good catch, he makes preparations in advance by putting into the water strongly tasting substances. A bow-net is baited by putting in it bits of chopped-up flesh or substances which have strong savour. Some baits are better than others because, other things being equal, they give out a more attractive flavour. Flavour and not odour, though the two often go together. Odours are for us and for the fisherman, the flavours are reserved for the fish. Judging by ourselves, we should be tempted to call such sensations olfactory, and the organs which assure them are in fact called olfactory, so identical is their behaviour. In reality, it is all a matter of liquid substances in a liquid water, and what we find is a real sense of taste of external origin like a sense of smell.

Now we can understand what the senses of fishes consist of, and how they are exercised. It is the same with the other creatures living in the same environment. The sense of touch, so useful on land, is less necessary here. The density of the water, making bodies lighter, lessening the action of gravity, makes it less important. To affect its sensitivity the organism needs other excitants than contacts. They are too clumsy for it. It must have vibrations, radiations of energy, reactions which can make themselves perceived. Impressions of taste are among the last. The water, among the pro-

ducts it carries along, either normally or by accident, contains substances endowed with savours which the creature perceives, whose intensity it measures, and these govern its behaviour. The living automaton is set in action accordingly.

To return to the comparison we have already made, the fish behaves like the dog, like land animals possessed of an olfactory flair. It has a flair of its own, and exercises it by taste. It receives tasty emanations coming from various directions. They make an impression upon it. Then it reacts to this action of the environment, and shows its reaction by moving. The dog perceives tracks on the ground; it goes, comes, turns and returns until it has "found". Likewise the fish perceives the real and diffused currents which bring it substances possessed of savour; it swims about and searches until it too has "found."

In an old song, little children are taken by a fairy to the temple of gluttony, where the floors are paved with sweets, the walls covered with cakes, and the ceiling with nougat and marzipan, something to please every taste. The world of waters is a realization of this idea; it is a world of savoury things. The creatures which inhabit it are bathed in sapid effluvia; they have only to choose. The world of air and land is a world of odours, and the dwellers in it are only reached by odorous effluvia, transmitted by the air which surrounds them. Both are alike and yet contrasted; they deal with different situations by identical means.

But when we take all things into consideration, the world of waters seems better served. Savour has the advantage of odour; it arouses more powerful, more attractive, more prolonged sensations; it is more closely bound up with the satisfaction of feeding, and this is one of the main satisfactions of life. The fish tastes slowly and deliberately. It begins to taste before it has seized its prey, and this tasting makes more impression than the sniffing of some slight odour; it goes on tasting as

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it snaps up and swallows its prey. If, like us, it had ideas and feelings based on its sensations, and if it followed them in its search for satisfaction, we might call it the king of epicures. Fishermen, considering its behaviour, seeing how it perceives their bait, goes away, comes back and finally, after much ado, swallows it, arrange their tackle accordingly.

CHAPTER XVI

WHAT THE FISHES SEE

There is no doubt that fish can see. But how do they see, and by what means are they assured of vision? That is another question.

So obvious does it appear that fishes see that it may seem ridiculous to assert the existence of a visual power or faculty in them. They have two eyes in their heads, eyes that are sometimes very large indeed, and these look like those of land vertebrates and seem to be their equal in complexity. So, without looking further, we conclude that they are equal in function, or at least, very similar. On the other hand, fishermen know that, in some of their tackle, in several methods of fishing, they must take into account the visual powers of the fish they hope to catch. A real faculty of sight certainly exists. But is it like our own, and, like our own, is it regularly exercised all the time, as a matter of habit? When the angler casts his fly, he sees it in the air and from above, but his impression of it is quite different from that of the fish, which sees the bait from below and through the water. The lake trout, living in dark depths, can hardly use his eyes as does his sister, the trout of the streams, which dwells in a stream thoroughly penetrated by the light of day. The fish of the ocean bottom, living in regions entirely without light; though they have eyes, are yet in the same negative situation as regards vision. Here is a puzzle, which we may, if we wish, refrain from trying to set ourselves, but which becomes interesting the moment we allow ourselves to think about it. We must not be content with the general opinion which takes things too much on trust and is

too ready to answer the question affirmatively. And as for any other opinion, we have first of all to find one.

I set myself the task of finding out what I have noted from time to time, and go through my notes. Starting at the beginning, with an example which best seems to support the case for perfect vision, I find the remarkable case of the Basilisk Blenny. This little fish belongs to the family of Blennies, whose suppleness and agility in leaping and swimming, whose strange attitudes and brilliant colours, I have had occasion to mention elsewhere. Relatively almost as lively and active in the water as the humming-bird is in the air, equally gorgeous and sparkling, the blennies, whatever their species, are remarkable for their hue, their variety of colour, and their swift undulating movements. There are some with black coloration, with an iridescent dark lustre. There are others fawn coloured, with purple patches, or spotted with brown and yellow in marble-like markings, or with cross-bars, either in delicate stripes or in broad bands. Some are green, a grass green, speckled with blue and gold like tiny flowers. In one, the large fins are of the same colour as the trunk; in another, they are different. Every conceivable hue is to be found in these little creatures which haunt the waters near the shore. They glitter and flash like living gems, with a delicacy never seen in the world of air. A blenny out of water is a dull, uninteresting thing. How different it is in its element, the water! To look at one is a feast for the eyes, especially when, by its means, we may hope to find out what it really is, especially as regards its powers of vision.

In European waters, the Mediterranean is the richest in blennies; it has twenty or so species, and, usually, these are found in rocky districts, where rough broken rocks are carpeted by green and brown seaweed, in water where, though the light is softened and attenuated, it is still fairly bright. On their heads, most of them

have branched tentacles like plumes which serve as tactile organs. But the basilisk blenny has none. Its small head, absolutely bare, with a thick crest on the top like that on a helmet, with a snout curved like a beak, reminds one of the head of a parakeet. Its greenish-grey body, with a suspicion of rose, barred and striped, seldom exceeds six to eight inches in length. But despite its small size, it does not pass unnoticed whether it is resting on its pelvic fins or swimming in its undulating fashion.

It is particularly common in the warm southern regions of the Mediterranean. The aquarium of the oceanographic observatory at Salambo in Tunisia has always several specimens in its tanks. I have had the opportunity of studying them there and noting the perfection of visual sensation, a perfection which I have never observed with such clearness or so consistently in any other species of fish.

The two eyes are small, but brilliant and protruding. Not far from one another, on each side of the projecting crest of the snout, they are set in a kind of hook-nosed face. They do not simply reflect the luminosity from without, they shoot glances here and there; these small creatures actually look about them as a land animal does. Their movements are suitably co-ordinated, and they turn together in the direction in which they have to look, and so secure the advantages of binocular vision. To make this exception still more marked and clear, the head, as a result of a flexible articulation not possessed by other fishes, can turn a little to the side at which the eyes are looking, thus co-ordinating their sensations and improving their vision. This is a really remarkable arrangement which allows this fish to direct its sight as a land vertebrate does, and turn its head to see the better. It is a surprising example of adaptive resemblance in a species which has no sensitive plumes, but seems to make up for the lack of them by an improvement in its powers of vision, and by movement of the

eyes to secure impressions which the other sensations cannot afford.

This condition is associated with not less surprising habits, in which we observe a connection between optical sensations and the phenomena of memory. Memory is primarily a matter of vision; this is made clear, as it were in a nutshell, in this little fish. It runs readily to cover and takes shelter. It chooses a lair, settles in it, makes a house of it, and seems to consider it as its personal property. One of the basilisks I examined had made its home in the empty shell of a *Pinna*, a large bivalve mollusc; it fitted its body into the interior of the shell, and put out its forepart through the gap left between the lips. Using the gap as a window it surveyed the neighbourhood. Its keen eyes, always on the watch, turned in all directions, and the turnings of the eyes were accentuated by movements of the head. If doubtful creatures swam up, it either retired and hid itself completely, or came out to meet the enemy and put him to flight. The course was decided by the size and presumed strength of the intruder. Sometimes, for no apparent reason, it left its shelter, took a stroll round the tank, then went straight to its place without any apparent hesitation, guided by a precise topographical memory. Then it took up its position again, entered the shell completely, turned round and finally put out its head. If, in the course of its stroll, it met one of its fellows, they both stopped, turned round as if to recognize one another, then separated, each going to its house, never making a mistake. It behaved exactly like an intelligent little being, capable of managing its own affairs quite well. As I watched it I could not help thinking of the little land animals, rodents or insectivores, their earths, holes, and hiding-places. There was a real resemblance in almost every respect. This blenny went about like a mouse.

But when we come to results, this comparison, however justified it may be as regards the creature itself,

fails. The land creature, living in air through which the light passes without hindrance, can see a long way; the water animal, bathed in water which scatters and diminishes the light, has its powers of vision definitely limited. Its surroundings hamper rather than aid it. The basilisk's field of vision is limited to its immediate surroundings, and can extend no farther. When I had carried out experiments on this fish, with its coloured plates of dissimilar hue, with regard to the visibility of colours, I discovered that some, those of the blue section of the spectrum, have hardly any effect on it, whereas it is more sensitive to those of the red, and especially to yellows and oranges. I tried to find out the distance at which this sensibility is effective. Usually, nothing could be noted beyond twenty-four to twenty-eight inches; and this was obviously the limit of the creature's normal vision. Moreover, the impression was keener when both eyes could observe together, and not so keen when the vision was limited to one side.

There was further evidence of the importance of binocular vision in these remarkable little fishes. I noticed that my finger, when I put it into the water near them, interested and attracted them even if I kept it still. They came out of their shelters, approached it, and tried to nibble at it. But this only happened if I put my finger directly in front of them; nothing happened if I put it anywhere else. If I went forward on one side, so that the finger could only be seen by a single eye, I could see that eye turn and follow the movements of my hand, but the head did not move; it was as though it perceived the movements without realizing the nature of the object. On the other hand, if I put my finger in the water in front of both eyes, so that both were attracted at the same time, there was no hesitation about the reaction. The object was perceived and the fish came out, drew near, and bit.

The other species of blenny in the same tank, or in neighbouring tanks, had nothing of the sort to show.

With their heads bristling with tentacles and plumes, they seemed less awake, less easy to interest, more indifferent to visual sensations. Their possibilities are less than those of the basilisk. They settle down in shelters, hollows in the rocks or fragments of shell, but they change their abode; they go and come without showing anything which seems equivalent to the co-ordinated actions of their neighbours. They are lively and agile, but do not respond so quickly, or so perfectly, to the optical stimulations they receive. They do not occupy so high a place in the order of sensation.

And so with most other fishes which make their abode in holes, or settle down in the mud and sand of the bottom. Their visual sense is stimulated only when there is obvious movement and vivid colour in objects, within the bounds set by the refringency and dispersive power of the surrounding water. And, further, in order that this sense may attain its fullest development, a simultaneous vision by both eyes is required.

This simultaneous binocular vision is found in quite a number of fishes, though it is lacking in those whose eyes are placed too much on one side. The eyes, in fish living in their normal environment, are not the shrunken organs, drawn back into their orbits, which we see when they are dead; they project like convex disks, and their full cornea, jutting out, receives the more readily the radiations of light. Consequently, their interior parts, thus bulging, are able to gather up the rays which emanate from an object, and give the fish some of the advantages of binocular vision. The field of this vision is undoubtedly restricted: it cannot be compared with that of land creatures which have stereoscopic vision, but it does exist, although limited, and can offer the same possibilities, although on a lesser scale.

Fishes which pursue their prey have an advantage; their vision becomes clearer when they look forward and above them. A pike or trout can hardly see a

possible victim which passes beside it, however near it may be, if it only comes within the purview of a single eye. On the other hand, if this moving prey, suspended or swimming, happens to come within the range of vision in front, they immediately pounce upon it. Their eyes have seen. This field, in which the two eyes overlap by a narrow segment of the retina, has a manifest superiority over the lateral field, although here the whole mechanism receives the visual rays. It may be smaller, but it is more effective in use because of its greater keenness. It is particularly in this field that the fish is capable of sight.

The swimming species of fresh water and the surface waters of the sea, whose regular abode is illumined by the light of day, are mostly sensitive to the light. It is possible to experiment upon them in the tanks of an aquarium, and to observe that their vision is affected by the power of light, and the colour and movement of objects. Their eyes, which can move in their orbits, turn in the direction of bodies which move a short distance away, as if these alone were capable of producing a visual impression. Form seems to be of no account. The same object, in identical conditions, will arouse the impression if it moves, if it is brilliant, if its colours are bright; but it will not stimulate it, or will stimulate it less, if it stays motionless, or if its hue is dark. The visual world, in these fishes, is confined to a limited region, and is made up of movements and flashes: shape has little to do with it. It has neither consistency nor permanence. It is entirely a matter of chance.

But however inferior this sort of vision may be, there is a still lower grade, that of the fishes, most numerous of all, which live in the gloomy regions of the sea, from four or five hundred feet down to the greatest depths. I have frequently been able to examine them while they were still alive, coming from the fishing-boat which brought them up, and I have always been

struck by the expression of their eyes, or rather the absence of all expression. These eyes, which are sometimes huge and take up the greater part of the cheeks, have nothing to show but a torpid and empty depth, like those of some blind men who, by the very wide-openness of their expressionless eyes, give evidence of the insensitiveness of the retina. They look as if they did not see at all. In these fish the enormous eyes are there, but they fulfil no function. They are of no use for the purpose which one expects of them, but they have their place in the structure of the head; they are a part of its architecture, and in that respect contribute their share to the organic shape, but, as regards visual sensation, they contribute nothing. In their dark environment, in that vast mass of water which so soon puts out the lights of animals with sight, there can be no part for them to play. These fish must have other sensitivities to guide them, other mechanisms, and these are taste and vibration.

In spite of apparent resemblances, there is considerable diversity in this respect. If, save for a few exceptions, all fishes have their eyes similarly situated and of the same conformation, showing no more than differences of size, there are marked contrasts to be observed in the manner of their employment. For that matter, we find such contrasts on land. A bird of prey, several hundred feet up in the air, can, with its keen vision, see a rabbit in a field, whereas the rabbit finds this distance too great for its visual equipment and does not see the bird. Hence the bird is able to prepare its swoop, pounce upon its victim, and grasp it in its claws before that victim has a chance to escape. When the rabbit does espy its danger, it is too late.

However, both sorts of eyes, those of vertebrates in the air and those of the water vertebrates, have practically the same structure; the same parts work in the same way. This difference in the keenness of vision

has its cause in another peculiarity; it is due to the intimate structure of the most important parts of the mechanism. At first glance these parts, the crystalline lens and the retina, seem alike, but there are many respects in which they are definitely unlike. The eye

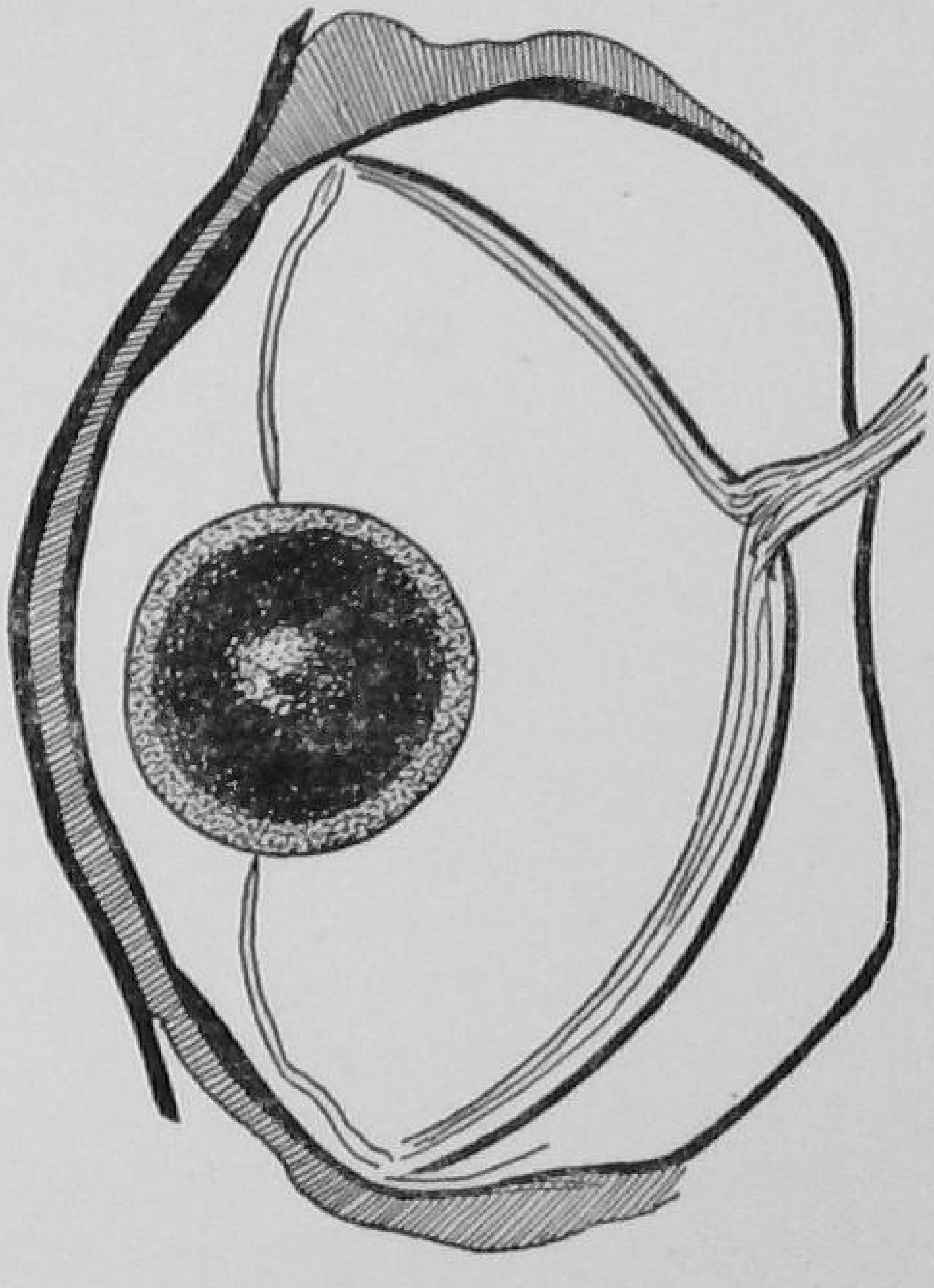

FIG. 48.—Simplified and enlarged median section of a Basilisk Blenny's eye. Left, the circular section of the globular crystalline lens; right, the optic nerve spreading out over the retina, the whole being surrounded by the enveloping membrane of the eye. Magnification, 15 times.

is a sensitive organ made as an optical instrument, and, if we wish to understand how it works, we must, so to speak, pick the mechanism to pieces, and examine it both as regards its essential structure and its way of acting.

Our own eye may serve as a starting-point in this investigation. We know the nature and purpose of

the crystalline lens and retina, the one a biconvex lens producing an image, which is projected exactly upon the other at one point, the central cavity or *fovea*, where the principal visual elements, the cone-shaped cells, are most numerous. These elements are rod-like cells and cone cells, so called because of their form; the grouping of them is more compact in the *fovea* itself where the cones are almost exclusive. A layer of pigment, situated at the point of contact of these rods and cones, arrests the luminous rays, absorbs them, and enables them to make their impressions. The diversity of land vertebrates, as regards keenness of sight, depends, for the greater part, on the number of these sensitive elements and the way they are apportioned; a retina well fitted with them assures good sight.

But fishes' eyes are made differently. We certainly find in them a crystalline lens and a retina, enveloping membranes and transparent humours, but they are arranged in a different way and consequently produce different results, like optical instruments with identical mounts but different combinations of glass surfaces. The crystalline lens is globular. In the living animal, it looks like a translucent sphere; when the fish is cooked it is this which forms the hard white ball which is removed from the cavity of the orbit, its substance having been coagulated by the heat of cooking. The retina is often supplied with an abundant pigment which permits of the absorption of the slightest ray of light; but the sensitive receiving elements are few in number and are often scattered, seldom collected in sufficiently large numbers, except in certain more favoured spots. When we construct an optical model based on such an arrangement and compare it with that of land vertebrates, we find that there is considerable inferiority in the working. The spherical crystalline lens, situated in front of the retina, can only project confused images upon it. Further, the retina

itself, with its receivers scattered at some distance from one another, cannot fix these images and makes them sensible in a lessened degree. The eye is weak. Compared with our own, it seems to suffer from long-sightedness aggravated by an extreme weakness of the retina. In the best instances, it has a certain capacity only within a restricted visual field, especially in eyes capable of binocular vision, in which the sensorial elements are grouped together in greater number, and sufficiently closely.

This brings me back to the eye of the basilisk blenny, its retina, and my study of its conformation. I find that the retina, in this species, has a *fovea* rich in cone cells; consequently, its visual function can achieve the degree of keenness described. In the other parts I find rods and cones, the former being grouped in bundles alternating with the latter, which are more isolated. This complexity of structure denotes, as we are led to expect by the creature's behaviour, a considerable functional capacity. But there are many factors working against such a superiority, preventing the creature from obtaining all its advantages; the lens is globular, too near the retina to project a clear image upon it; the nerve-cells are too few to refine the sensorial perception adequately. But this eye, with a retina well equipped, is an exception. In most other fish, the retina has no *fovea*, the rod-cells are more numerous than the cones, and they are spaced out instead of being grouped. All this is a disadvantage, which, with the defects of the crystalline lens, causes the vision to be of an inferior quality.

There is no essential identity between the eye of the fish and that of the fisherman who tries to catch it. They do not both see the same thing. The two organs may seem, taken as a whole, to bear a striking resemblance but, in reality, they differ in many particulars. They are like two houses which are identical as regards general oútline, but of which one is fitted

with all the fancy details of luxury, whereas the other has only a few clumsy pieces of rough furniture. Or, since we are considering optical systems whose purpose it is to form and project images of external objects, one might be compared to a first-rate camera, fitted with a perfect lens, with exact focusing and very rapid plates, while the other is like an old-fashioned piece of

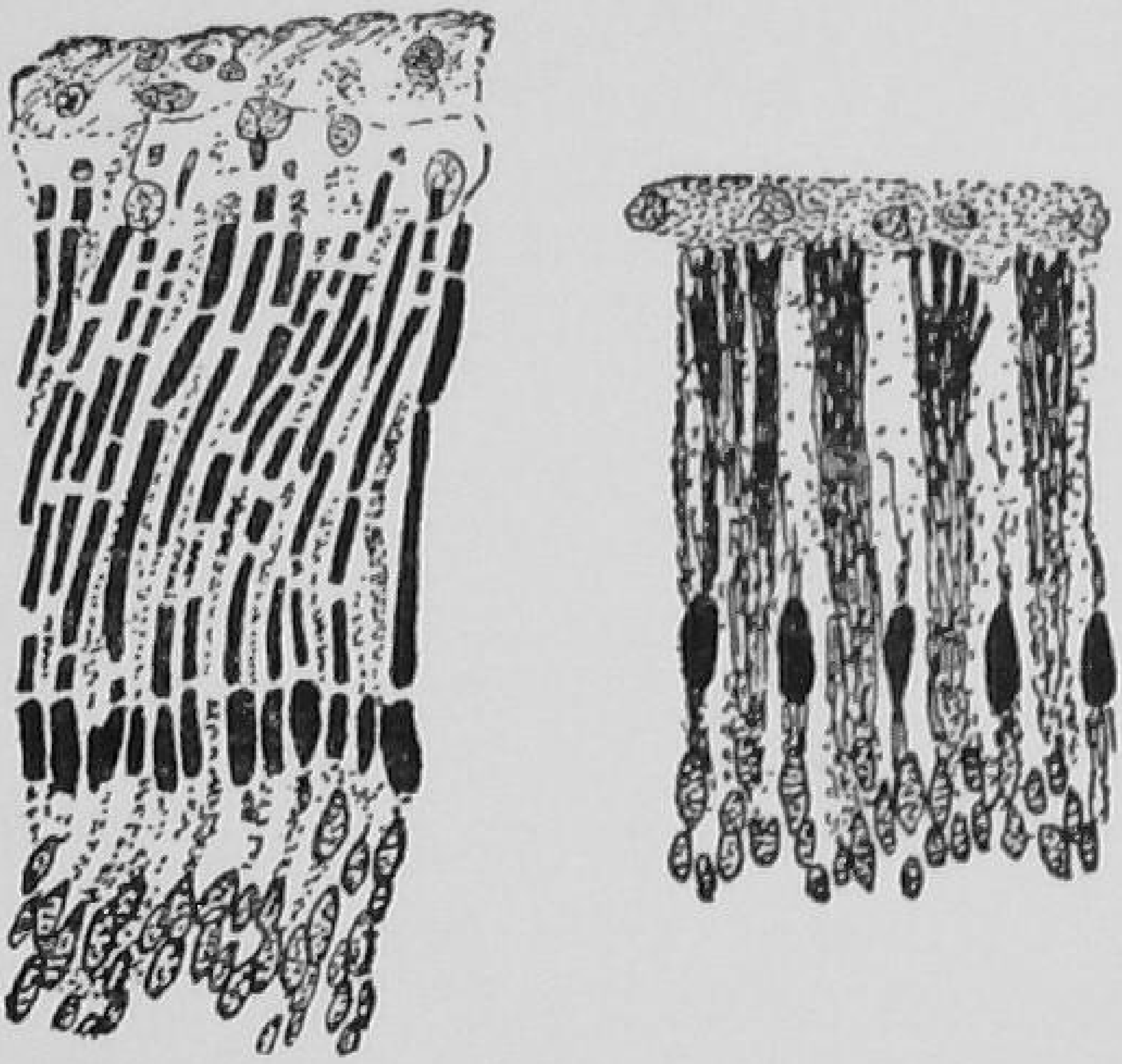

FIG. 49.—Greatly enlarged details of the structure of the retina in the Basilisk Blenny. Left, construction of the *fovea*, composed of cone cells only (in black). Right, the structure of the rest of the retina, showing bundles of rod cells, alternating with individual cone cells. Linear magnification, 600 times.

apparatus, with a badly cut lens, focusing of doubtful accuracy, and inferior plates. The former gives precise, clear, and faithful reproduction, while the second produces a picture which is blurred. The image is there, but it is confused, flat, faint, often unrecognizable. The fish's vision is blurred too. The refringency of the water in which the fish lives exaggerates this fundamental defect, so that it sees as though in a fog, and even the most fortunate can see only objects which are close by.

Must we therefore apply to the fishes the Biblical

words about those who do not believe: "Eyes have they and see not"? In spite of the apparent paradox of the answer, we must admit that it is true of the species which live in the dark regions of the world of waters, those zones of complete darkness which, as a matter of fact, make up its greatest part. As for the fishes which are nearest to ourselves, we cannot, indeed, flatly deny that they have sight, but we must allow that they see only a little. On the other hand, this "little", so far as they are concerned, is relative. Our own vision is more perfect, and we can use the expression only in relation to our own better capacity for seeing. The "little" is as much as the fish needs. Its feeble visual capacity is sufficient for the life it ordinarily leads in the waters.

We use the word "vision" for a complex phenomenon in which we associate comprehensively several partial sensations which, although they are all visual, are practically independent. When we perceive an object, we perceive its contours, its colours, its movements; the image of all this is projected upon our retina, and the retina is sufficiently perfect to accept it as a whole and make it sensible to us, making everything perceptible at the same time. But the three sensations are actually distinct, none the less. We connect them up, we make a unity of this visual triad, but each has its own particular manner of working. We may presume that there are retinas in which these sensations are not present as they are in our own and in those of a good number of land vertebrates, retinas where they are perhaps more separate, in which one grows weaker while the others remain unaffected, or do not weaken to the same extent. So it is with fishes.

Their eye produces a blurred image, certainly, but this is true only as regards forms and contours, because the image is imperfectly produced. On the other hand, the relatively large proportion of pigment in the retina causes it to be easily influenced by brightness

or the colour of bright objects, even by a very slight degree of luminosity. As regards the perception of movements, that causes no difficulty, because of the displacements of the image, confused though it may be, projected upon the retina, and the succession of perceptions which results. The vision may be weak in comparison with ours, but it has a certain definite capacity.

We may now try to represent to ourselves the visual world of fishes, at least that of the fishes which have one, since they usually live in zones traversed by luminous rays which the retina can perceive. Doubtless it is not very different from the world we see when we are plunged into darkness or enveloped in a dark uniform fog. Objects appear like stains, varying in appearance according to their brightness or hue, varying in size according to their mass, and of undecided shape. We can see their movements when they go from one place to another, or when we move ourselves; sometimes they fade out and disappear, sometimes they become progressively stronger. We see them better when they are straight in front of us; we turn to them to distinguish them the better, to draw near them or to avoid them. Suddenly, when we are quite close, we see them more clearly; we discern colours, contours, shapes, which vanish again as soon as we draw away from them. In short, in fact and in appearance, this visual world has neither distances nor contrasts. The light weakens in it, becomes uniform, confusing instead of distinguishing. From moment to moment, in one place and in another, there rise up bright spots which take form as they approach and fade into nothingness as they go away. Nothing stands sharply out as in the air. Everything comes within a field of gradation from grey to black.

The story of the visual organs and of vision itself is very interesting, if we follow it out throughout the

animal kingdom. There, as elsewhere and perhaps better than elsewhere, we realize the importance of the work of life in its dual action, morphogenetic or organic construction, biogenetic or utilization according to possibilities. To sum it up in its main characteristics would lead us through a long and suggestive series of episodes. We find the most elementary stage of it in that latent condition, not yet established, in which the skin is sensitive to radiations of light; the future faculty of sight is nothing more than an indistinct, confused sensibility, without any definite organs devoted to its purposes. It displays itself more definitely at the higher stage when the pigmentary patches capable of absorbing light and increasing its influence establish themselves in various parts of the body. We then have a condition of sensitivity to light, but not yet vision itself.

This appears when the crystalline lenses and retinas form; the former projecting images which are collected and made sensible by the latter. We find the first experiments of this sort exemplified by most groups of aquatic animals in their different ways. Sometimes the lenses are too large and badly situated, and can only concentrate the rays without producing definite images; sometimes the retinas are too small or insufficiently innervated and can only give sensations of luminosity, of variations in the lighting, of coloration, and can do no more and no better. Many of these eyes, with a structure imperfect as regards optical equipment, sometimes in a bad position in the organism, give only a slight result and play only an unimportant part, despite the appearance of complexity they present. As regards structure, they seem equal to eyes with a true power of vision, but they are far from equalling them as regards function.

We must go back to the Cephalopod molluscs like the squid, cuttle-fish and octopus, or the higher crustaceans, crabs and lobsters, which are unique

examples of multiple ocellary composition, and especially to the fishes, to find eyes which, situated in the most suitable place in the body, have a conformation specially designed to produce a real vision of external objects. The lens is sufficiently distant from the retina to allow images to appear, though they are very often confused. Again, the membrane of the retina is sufficiently full, sufficiently rich in sensitive elements, to give the visual sensations an importance and a degree of co-ordination by which the individual is able to profit. It better determines the behaviour, and governs it to better effect. The visual faculty now exists, on a small scale, limited by the physical conditions of the medium in which it is exercised, but still effective.

It is only in the world of air that vision becomes the vision we ourselves know, which is known also to several of the creatures by which we are surrounded. The light transparent air allows the rays of light to pass without retaining or absorbing them; this change of physical circumstances itself brings about a considerable improvement in the functioning. The crystalline lens cut like a biconvex lens, fitted with an accommodating mechanism which keeps a continual focus, projects clear and detailed images upon the retina. This is where vision becomes really good.

Visual sensitivity is thus made perfect by stages. It rises from a simple perception of luminosity to that of intensities of lighting, then to that of colours, of movements, and finally to that of forms, first diffused but progressively more precise. Then consciousness penetrates to the very depths of that marvellous domain in which the emanations of light go forth. Now everything is accessible to it, and henceforth everything is its own. It makes its proudest, its most splendid conquest. The many-hued realm of the energy of light is fully open to it. But this is true only of the worlds of air and earth. That of the waters, staying at the threshold, has but its crumbs,

its final accents. The dark, primæval environment—in this respect it preserves its original obscurity. Life, born vast ages ago in its depths, has, by degrees, raised itself towards the light, to reach it, to capture it directly, to rejoice in its glorious shining; but this result has come about by the exercise of other powers than its own.

CHAPTER XVII

THE VIBRATORY SENSE

Calling the fishes! Of all the varied occupations of the fish-breeder which seem so extraordinary to the novice or the visitor, this, more than any other, is calculated to arouse interest. There is such an occupation, and it is a very practical one; the breeder actually does call his fishes which have been scattered; collects them, and urges them to come to him. The shepherd whistles to his dog with the same intent; the farmer's wife calls her chickens; both make use of the auditory sensations. These are addressed to the ear. The fish-breeder does the same thing. But he makes use of a sense related to the auditory, peculiar to fishes, which influences them sufficiently to turn them from their course, and finally bring them to one place.

The means is simple; he has only to impress upon the water a series of slight concussions. The fish-breeder taps his foot several times on the edge of his tank; or claps his hand against its brim; or, if he is in a boat, he taps the bottom. Nothing more is needed. The concussions, transmitted to the water, form vibrating waves which reach the fishes and are perceived by them; they obey the instruction and come to the place whence the waves set out. They possess a special sense which gives them knowledge of the waves, teaches them the direction from which they come, and enables them to take their bearings, and finally, to govern their behaviour according to these vibrations in the surrounding medium.

Various factors make this easier than it would seem at first sight. Their body, suspended in a medium

the density of which differs only slightly from their own, feels to the full and without any hindrance its movements and any oscillations which occur in it. There is no difficulty about the transmission, whereas in the air, the vertebrates, whose body is weighed down by the force of gravity, are incapable of feeling such vibrations, or experience only the most intense as impressions of touch. The fishes have the added advantage of possessing a sensory apparatus, definitely constructed for the purpose, which localizes, amplifies, and makes clear the perception. This apparatus consists of tiny pits, richly supplied with nerves, situated in a straight line along each side of the body from behind the head to the end of the tail. Thus set in a series, close to one another, they look like a line traced from one end to the other of each side of the body; hence the name "lateral line" which has been given them, an expression which conveys a fair idea of their general appearance.

The possession of this sensitive apparatus does not interfere with that of genuine auditory organs placed, as is customary, in the thickness of the lateral walls of the skull. But these are very small, and comprise only internal ears, of which the principal parts are the semicircular canals. From the small dimensions of the other parts of these ears, we may presume a correlated reduction in functional efficiency. It seems likely that hearing is not their principal purpose, but rather that of orientation in space, of changes of direction, of the equilibrium of the body in its medium, in conformity with the predominance in them of the semicircular canals. Certain anatomical dispositions, moreover, corroborate this. In the carp family and those related to it, the *vesica natatoria* is bound to the internal ear by the intermediary of a chain of ossicles; and this air-bladder filled with gas being the first to experience the effects of change of direction and equilibrium, being also the organ which best feels

them, its direct relations with the sensitive centre appear to facilitate the fulfilment of such a function.

But fishes really hear in quite another way through the action of the lateral line, placed exactly where it is best fitted to perform its function. Considered in detail, on the side along which it passes from end to end, it consists, usually, of a series of tiny pores, placed in a row, which can be seen by the naked eye or with the help of a lens. Each one, when there are scales, goes through the whole thickness of a scale, and the scales, thus pierced, take on a peculiar appearance, in several cases even acquiring certain additional characteristics. When a species is described, these particular scales are given separate mention, sometimes as regards their shape, always as regards number. They are called "the scales of the lateral line", and counted, the total figure, which varies from one species and one genus to another, being given. This figure is a measure of their size. A species with small scales has more of them, proportionately, than its neighbour with larger scales. The lateral line, despite the simplicity of its appearance, thus acquires its full significance, and shows that its little holes possess a value beyond dispute, that it is much more than a mere ornament.

Each of these holes is the outer orifice of a short, narrow, and often oblique tube, which opens, below the corresponding scale, into a longitudinal canal, broader and continuous. This canal is an interior part which runs along the side underneath the row of perforated scales, putting out, one after another, below each of the latter, the tubes which open to the surface. It is accompanied, in turn, by a nerve called the "lateral nerve" which, all along its length, gives off branches to the series of tubes. Each of these ends in microscopic sensory centres, the principal elements of which, constructed on the same model as those of the auditory system, consist of cells terminating in

filaments. This organ of the lateral line is an auditory apparatus of simplified structure which spreads out in length instead of being arranged in a compact mass, and communicates with the external world through all the orifices with which the scales dependent upon it are pierced. The size of the nerve is evidence of the importance of the part it plays. And this nerve, originating in the brain close to the auditory nerve, shows a real community of connection and function with that nerve. The lateral line, like the ear, is the seat of a vibratory sensitivity.

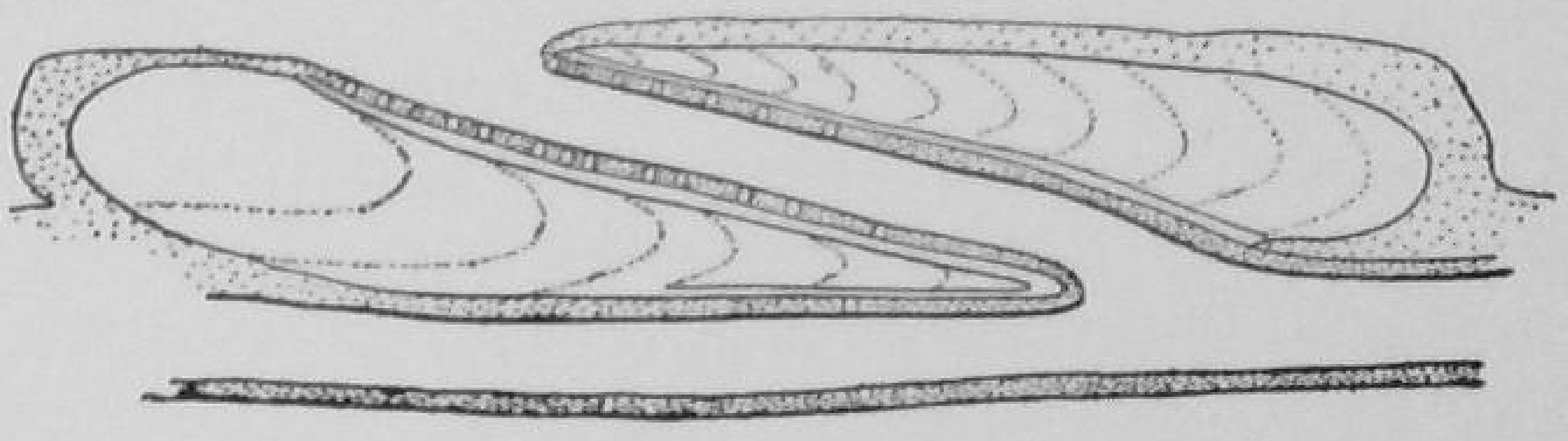

FIG. 50.—Simplified and enlarged representation of a section through a scale of the lateral line of a Red-eye, showing the tube which passes obliquely through the scale and opens, on the one hand, outwards, and, on the other, into the longitudinal canal inside the creature. Linear magnification, 30 times.

Its mode of functioning is to be understood from the manner of its construction. The holes which open outwards receive the concussions which pass through it directly from the surrounding water. They transmit them to the mucous liquid with which the tubes to which they give access are filled. As this liquid also bathes the sensorial centres inside the apparatus, the vibrations directly affect the filaments whose business it is to receive them on the sensitive elements. They are thus perceived.

This remarkable arrangement is peculiar to fishes; the species which do not have it, or in which it is limited, are in the minority. We also find it frequently in the bodies of the young Batrachians. Its presence

is in keeping with the needs of a completely aquatic life, with branchial respiration. It is absent in Cetaceans, which have lungs and perfected hearing organs. When it does exist, it adds its field of action to that of the little auditory organ proper, and provides a measure of wealth to what, without it, would be poverty or destitution.

Its field of action, partaking at once of touch and hearing, is considerable. It includes the vast register of ultra-sounds, of the vibrations imparted to the water by the passage of a resistant body even some distance away, or by the movements of objects close at hand, by shocks transmitted from afar, or even by currents from time to time. Water being incapable of compression, these various forms of concussion are easily transmitted. The listening apparatus used by sailors and hydrographers enables its users to hear the propeller of a ship several miles away. The organ of the lateral line is, after its own fashion, a listening apparatus with several tiny receivers; thanks to its structure and its position it is able to receive and perceive sensations which would escape the ordinary auditory apparatus, the ear itself. It has its own register, concerned with deep tonalities, multiple and varied.

The fishes do not hear exactly as we do, but none the less they hear. If they are deaf to the majority of the sound vibrations which we distinguish and which the air transmits to the water; if they feel them only slightly, and often not at all, they are, on the other hand, sensitive to vibratory shocks which we do not perceive at all, or which we do not receive in their way, for, according to circumstances, we should transform them either into a rough touch or a confused hearing. Thanks to their organs, these sensations in fishes are more intense and precise. Through them fishes acquire a knowledge of what is going on in the water around them. At every moment they control

their behaviour on the basis of these vibratory impressions which the water transmits to them; they come, they turn aside, or avoid and flee, according to the reflex provoked.

This sense, like the others, varies considerably. According to circumstance and in different species, its keenness is sometimes excessive and sometimes dulled. In rod-fishing, a duel between the fish and

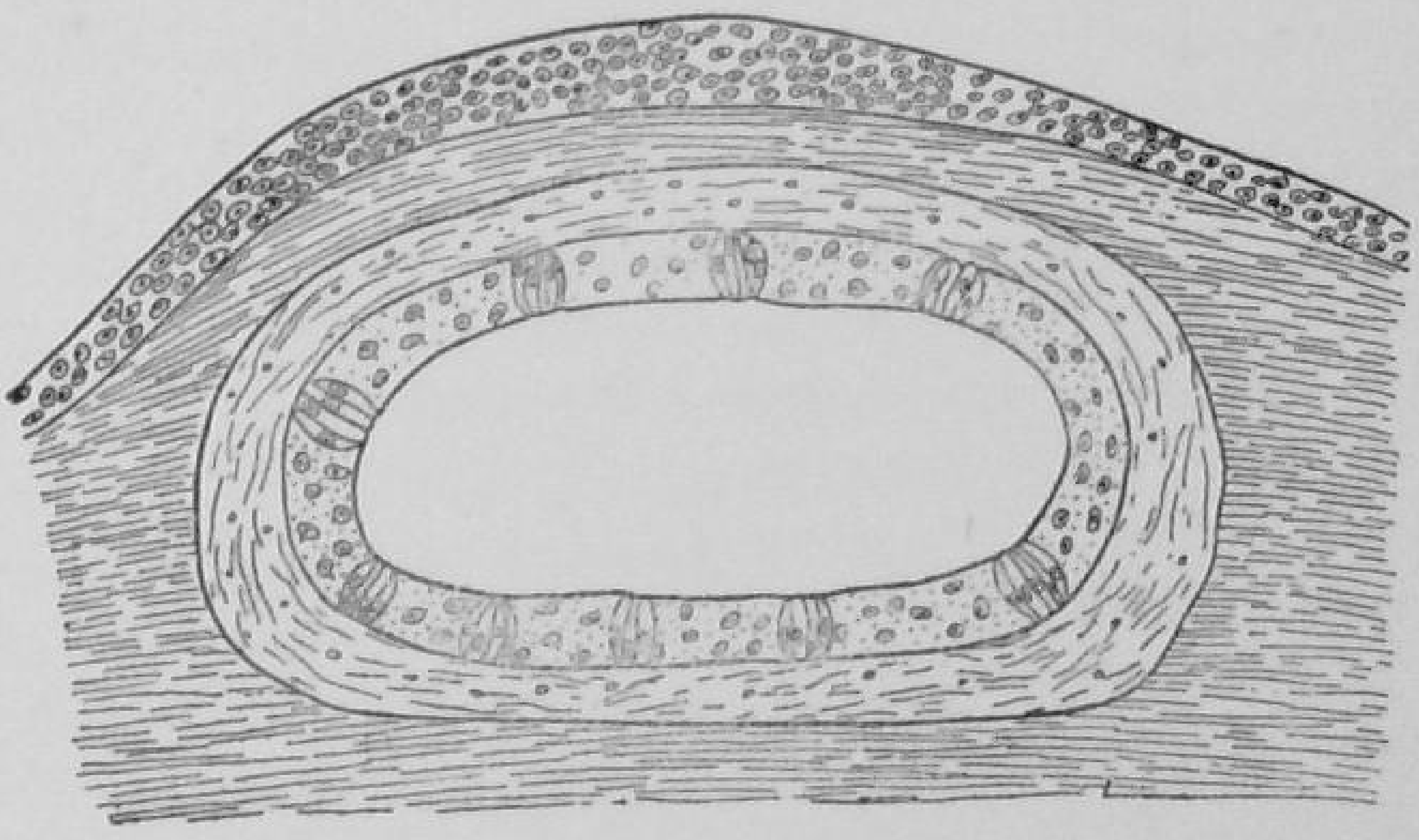

FIG 51.—Simplified and very much enlarged view of a transverse section of the tube which perforates the scale, so as to show the walls which, at intervals, contain groups of sensitive elements, both elongated and oval in shape. This wall is embedded in the substance of the scale, which itself is covered by the epidermis. Linear magnification, 375 times.

the fisherman, it often works in an unexpected way and plays a part which has not been taken into account. Sometimes its importance is less. In other cases it is exaggerated, as in the fresh-water roach. One of them, the rudd (*Scardinius erythrophthalmus*), stands out among the others on account of its extreme sensitivity. It is both greedy and distrustful; its appetite draws it to the bait, and its auditory sense drives it away; its behaviour, based upon both impulses at once, seems to leave it in a continual state of indecision. If one is fishing for it from the river-bank, it must be very

quietly approached, for the slightest shaking of the soil, transmitted to the water, is enough to put it to flight; furthermore, the line with its float must be fitted in such a way that there is no abnormal vibration; finally, it must be struck sharply, for the slightest oscillation frightens it off at a great pace. It shows, better than most fishes, how they are affected in various ways by their sensations. Its indecision is only apparent; in reality it takes one decision after another, but they work in different ways. Each time, the creature obeys the sense which happens to be predominant; it conforms its conduct to that sense; and, as the predominance varies according to the conditions prevailing at the moment, it acts according to the influence of that moment, and expends itself in a series of automatic and successive obediences.

The outer world is built up on the basis of the sensations experienced. That of a bird of prey, in which sight is predominant, is composed of shapes, figures, and images. That of a dog consists largely of odours and noises; its olfactory sense and acute hearing dominate all the rest. That of a roach is made up of tastes and vibratory waves. Transferring to the water the sensations which the dog experiences in the air, it conforms its behaviour to the indications given by its two principal senses, those of savour and vibration. It goes from one to the other, to whichever happens to be the stronger at a particular instant.

The life of fishes is a collection of, and a compromise between, continual reflexes. When we see these creatures in the water and consider the ease and flexibility with which they move about, we realize that they are strictly adapted to their surroundings, and that their organization accommodates itself completely to the conditions under which it is placed. The expression "As happy as a fish in the water" has become a proverb. And its behaviour is well regulated because the water itself, the environment,

governs it unceasingly. There is perfect adjustment, without anything to interfere. The organism, enwrapped by the water, supported by it, warned by its sense organs, regularly reacts according to the indications it receives. It is entirely submissive to them, for, in contrast to the higher vertebrates, it has not the regulation brought about by the constancy of animal heat. Its main psychology is based on sensations of the moment.

Fishes obey their many sensitive inclinations according to circumstances. If we use a scientific expression, we may say that they yield themselves, without any restraint, to all their tropisms, to all the automatic appeals produced and governed by the direct, immediate action of the medium in which they live. In order to preserve their organic well-being, they behave according to the stimulus of the circumstance of the moment, and immediately respond to the action of the environment by a corresponding reaction, their sensorial apparatus acting as a warning. What is called " instinct " in them is nothing but this response, the expression of the perfect harmony which unites the living creature to its surroundings.

The fish is a particularly sensitive creature. For purposes of observation I have occasionally posted myself in prominent places, points of rock or old tree-trunks, looking out over a fairly considerable depth of water, frequented by various species. Provided I made no movement, and appeared to be just another object, I could for quite considerable periods watch the comings and goings, the slightest inflections, the most fleeting response to sensations. I could secure a perfect picture of the intensity of life before me. Below me, the fishes moved without displaying the slightest uneasiness, going about their business without the least sign of fear. Each species has its own type of behaviour, but all are alike in the uniformity and continuity of their action. We feel that all these

creatures are, as it were, in a state of continual tension, incessantly receiving impressions from without and immediately responding to the sensations perceived. Suspended in a medium both dense and fluid, their movements are adapted to it; changes in the one are manifested by attitudes in the others. We find among all these modifications a continual seeking for vital equilibrium, for permanent well-being.

In the world of waters, no other group shows such an excessive sensitiveness. Even the largest and most highly organized possess only a few devices for sensation, and these are often ineffective. The fishes, with their lateral line, stand above the average. With its aid, the range of their sensitiveness is increased and extended to impressions which other classes of animals do not perceive, or accept only in a less distinct manner. The field of sensation in which the animal becomes conscious of what it is and of what it is capable, becomes in them vaster and more filled with incident. In this slow development of consciousness, from its beginning in the lowest creatures, the fishes take a high place. They go beyond the heavy materiality of their neighbours in the water, rising to a greater degree of comprehension, a clearer understanding of the objects which surround them. In a word, their senses are more refined.

But these senses stand alone in them, they are not supplemented in any way. The brain is still incapable of co-ordinating the sensations and storing them up so as to make a memory. When there is any recollection at all, it is often brief and limited. The lack of temperature adjustment, moreover, forces them to submit to all the changes which take place about them; they can neither avoid them, nor escape even for a short time. They are slaves of their environment, and have to put up with the consequences of this subjection. But there are advantages about it also; their environment supports them well, in fact abundantly.

In Neptune's flock they are supreme, and this superiority is their due; everything about them is fitted to ensure it.

In its behaviour, thus narrowly controlled by environment, the fish exemplifies the harmonious condition of a living being and the properties of the life which animates it. This harmony, effected by sensations and the movements which they control, is displayed in continual accommodations, which are made manifest without any disturbing element. The whole organism profits from its surroundings; it enjoys them to the very depths of its being; it perceives, it receives, and it reaps the benefits. Not only does it receive; it gathers up and concentrates into its substance, transforming and transmuting them, the various kinds of energy which pervade its world; it uses them to modify its own substance, and renew it continually. Its vital action is of an unequalled intensity, a never-ceasing continuity. Though the fish is lost in the immensity of its environment, it goes beyond it, in spite of its small size, by the greatness of its animation.

Heat, for example, simply passes through an inanimate environment, but it stays in living bodies, is absorbed there, and is used to maintain them. The fish in its water appears as the centre and the transformer of matter and energy; and other beings animated by life are, like it, centres and transformers. The flesh is continually drawing from the environment the material substances, food and oxygen, which it uses to build up its structure, to repair the losses caused by fulfilling its vital functions. In the same way, it accepts from it the radiations of energy which are able to bring about this reconstruction; it has machinery which makes it easy for it to take what it needs. It pushes to the highest degree the utilization of things for its own maintenance. Fighting all the time, it opposes its vigorous littleness to the almost inert hugeness of its surroundings, and, ever

since it appeared on the globe, it has always succeeded in winning the victory. This is a continual miracle of the creative Power which we seldom consider, so accustomed are we to consider it in itself or round itself, so accustomed are we to it, though, at every moment and in every thing, from the humblest to the greatest, its supreme and sovereign greatness is always present.

Life has this quality of itself; it makes it its property, and is thereby distinguished from what is not living. Living matter, with the inherent energy which animates it, is a special thing, unique in kind among all Nature. But, in relation to the rest, in relation to the environment through which it disseminates its individuals, it is a contained within a container. In this fact, despite its dignity and its independence, rest its weakness and its subjection. These material substances which it brings together to make of them the parts of its body; these kinds of energy which it associates and exalts that it may live, can only come to it from outside, can only reach it through the intermediary of the inanimate environment in which it is contained. Its independence is not complete; it is conditioned. Its quality depends upon that of the environment, and upon the way in which the environment behaves. Vital action has two tempos; it is divided into two parts, which succeed one another alternately. In the first place there is an action, arising in the environment, based upon what it is able to provide and what the living body can receive. Then there is a reaction, originating in the living body, and carried out in accordance with its capacity for absorption and transformation. The second results from the first, and, in this way, the environment guides and controls action.

The organs of sensation, in these processes of guiding and control, have more expression and significance than any others. They become almost symbolic. The roach, drawn by its sense of taste

towards a bait which might be its food, then driven from it by the vibratory sense which excites its distrust by warning it of an unaccustomed circumstance, excellently shows, by its responsiveness and its swift action, how these organs work to its advantage. They allow life to function, to continue, taking from the environment every possible advantage, drawing from it everything that it can yield, directing it towards those places where it can best subsist. They reach it by receiving the radiations of energy, waves and vibrations, and making them perceptible according to their intensity and direction. They reduce the inertia of matter and make it less servile. They raise life to consciousness and to appreciation. Matter, in and for life, is only a means and a support; it is energy, in fact, which forms and animates it. If both, of necessity, unite in the creature, it is energy which takes the lead and becomes dominant, for it is energy which leads to action. Life, a complex of energy, is really spirit.

CHAPTER XVIII

THE TOMB OF PEARL

Before me, on the table at which I work in my laboratory, lie four pearl shells. The name is commonly used to denote the large, thick, almost flat valves of the shells of pearl oysters which are eagerly sought because of the pearls they sometimes contain, and for the mother-of-pearl of which they themselves are composed. Although the shells of other molluscs are also made of mother-of-pearl, and therefore deserve the same name, especially since they are sometimes used in the same way, in this particular case the shell has a beauty, a compactness and size which give it a genuine superiority. The more so, because the pearl oysters, which live in the warm seas, often gather in large beds, like the oysters we eat, settle beside one another, and thereby offer fishermen an opportunity which they are not slow to take.

These four shells, which have come from the Caribbean Sea, where the pearl oyster beds are keenly exploited, do not differ in any essential particular from those we see in seaside shops with a picture painted inside them. They have two faces, one bulging slightly, which is the outer part when the oyster is alive, greyish in colour and rather dull; the other, inside, hollowed out, with the naked mother-of-pearl, white and sparkling, glittering exquisitely. But, on this pearly side, there is a special thickening not found elsewhere, a conspicuous, rounded, winding band, also made of mother-of-pearl. These four shells, selected because of that band from thousands of others, all have it, but it differs in size and shape.

The rarity and the lack of resemblance indicate that here we have an accidental case, and we are curious to know what it means.

I take up one of the shells. With the point of a scalpel, I break off in little pieces the surface of the pearly band. This, made of very thin layers, breaks up into small flakes, and I soon discover that it forms a sort of shell, enwrapping something, upon which it applies itself and models itself exactly. Patiently and carefully, for it is fragile, I uncover the object thus surrounded, and I find that it is a small fish, dead, of course, and petrified, with a longish body, caught in the mother-of-pearl and so preserved. I can discern its head, the eyes sunken in their orbits, the snout through which the bones protrude, and I can also see the fins, all the rays of which are preserved, and the whole body, in which the vertebræ may be seen one behind the other. This object is the mummy of a fish, preserving its normal form. The thick band which protrudes in the inside of the shell is a tomb of mother-of-pearl in which the mummy is buried.

It is not difficult to reconstruct the phases of the extraordinary event which has turned this oyster shell into a sort of mausoleum, wherein is a tomb in which a corpse is buried. This corpse was first impregnated with calcareous matter, as we may easily see if we treat it with weak acid. Thus embalmed, it was covered with one layer of mother-of-pearl after another, until it was completely surrounded. Nature had built for it a tomb of rare and precious stone, a magnificent coffin; she had done for this little fish what the Egyptians used to do for the remains of their kings.

This shell, in which the tomb is placed, once belonged to a pearl oyster. When it was alive, it had the structure of its fellows. Its body was sheltered in the large shell with two thick valves, and it con-

structured the shell itself by continually forming calcareous matter which spread in thin layers of mother-of-pearl one upon another. It was able not only to build its own house, but to keep enlarging it all the time, making it continually thicker, adding new layers to those which were already there. And, as the valves enlarged, the oyster grew.

For making the shell, the body makes use of two large symmetrical expansions which envelop it completely like a cloak, and, in fact, the name " mantle " is actually given to them because of their nature. These two parts of the cloak form and lay down, on their outer side, the calcareous matter of the mother-of-pearl of which the shell is made. If we examine a whole oyster when it is alive, we first separate the two halves of the shell and see that the calcareous mass is lined inside by a thin plate of living tissue forming the two expansions which make the cloak. In the spacious cavity which they bound, but occupying only a small space in it, is the body itself with its organs, the most notable of which are those of respiration, branchial plates lodged in the angle between the cloak and the sides. This type of organization is also that of other molluscs of the same class, though of different appearance, the " Lamellibranchs," the ordinary oysters of commerce, mussels, clams, etc., which also have a two-lobed cloak and a shell with two valves surrounding the whole body.

When alive, in their native waters, the pearl oysters, on the bottom where they live and where the fishermen gather them, leave their shell half open, and their valves allow the water from outside to penetrate freely into the large interior cavity. Two currents are set up, one going in and the other coming out, so that the water is continually renewed, bringing dissolved oxygen to the gills, and particles of food to the digestive tube. The thick, pleated edges of the mantle, which line those of the shell, have fluted contours so arranged

as to direct these currents into channels and take them where they have to go. Although they are fixed to one place and cannot move from it, the oysters thus receive what they need, and live in due conformity with the requirements of their particular structure.

They live so well that they swarm, however little circumstances are in their favour. Side by side, and even one on top of another, they form extensive banks, with little ones beside the big ones, and all together form large heaps spread out over the sea bottom. These banks, made of compact and strong shells, themselves serve as supports and shelters to other creatures. On them, under them, between them, flourishes a rich vegetation of seaweed, mingled with the rocky arborescences of coral. Bright-hued sea-anemones, different kinds of molluscs and other creatures, settle wherever they can find a suitable place. A regular population, varied and highly coloured, swarms and develops to an extraordinary degree upon this solid support. Fishes are there too, profiting by the number of likely victims, especially since they are so easy to secure. Some of them are particularly common, among them one whose existence, even more than that of the rest, is bound up with the oysters to such an extent that it deserves the name of "Pearl-fish" which has been given to it. It is this fish which becomes the hero whose end is to be a mummy encased in a coffin of pearl.

This fish belongs to the genus *Fierasfer*. Its specific name is *Fierasfer affinis*. In appearance it is like a very small eel, long and supple, undulating, slightly brownish in colour, with translucent tones and flashes of silver. The resemblance is only in form and appearance, for, in reality, *Fierasfer* belongs to a different group from that of the eels and congers, and has neither their structure nor their mode of life. In its ordinary state, it sometimes lodges, folded up on itself, in the interior of the pearl oyster, and makes its abode in the roomy

cavity surrounded by the mantle. The oysters live well, and the pearl-fish, settling down with them, finds shelter, if not a livelihood. Situated beside the oyster's gills, taking advantage of the entering current which flows towards them, protected by the thick envelope of the shell which covers the mantle, it can enjoy, in peace, and remote from every risk, the charms of a life of complete repose. It takes cover in this shelter which it has chosen. It enters through the space left between the open valves, and goes out the same way when the need of food compels it to do so; it returns again when it has fed. The fish asks the oyster to allow it to share the shelter of its shell and the oyster agrees; both live together in complete harmony.

But things sometimes go wrong, and the agreement is occasionally broken. It may happen that the visitor, when young and not very big, mistakes the door. Instead of passing through the opening in the edges of the mantle and so into the cavity to which it is allowed access, it tries to find its way between the mantle and the shell, to enter thereby into the private quarters of its host. Then the oyster defends itself and punishes the intruder. When the fish has forced its way into this private ground, the mantle contracts, tightens round it, and imprisons it against the shell. The intruder is unable to move, cannot free itself, breathes with difficulty and finally dies, where it is in the narrow gaol in which it has imprisoned itself. Caught in a trap, it suffers there the punishment of death. Then the oyster, not being able to get rid of the corpse, sets to work to embalm it, to mummify and to immure it. Its secretion of calcareous matter begins by infiltrating the tissues of the fish, and then incrusts them. The secretion continues and the new deposits spread in little blades of pearl which surround the mummy and gradually totally enclose it. Thus the tomb of pearl is built. Its presence, its position,

its contents, tell a tragic story which, transposed into human terms, would be that of a young rake who, as a result of the error of his ways, comes first to prison, then to death. If Nature uses a precious substance to make a coffin for him, if she adorns what she herself has done, she gives, none the less, an example and a lesson.

This story is that of an accident which happens comparatively rarely. It is brought about by a chance circumstance, the coming of a little fish into a place where it ought not to be. The consequences throw light upon the essential point, the continual production of mother-of-pearl, of which it is only an episode. The pearl-fish is not the only one to try to introduce itself between the shell and the mantle; other animals, even smaller, do likewise. The result is the same. Just like it, the intruders are immobilized, imprisoned, stifled, then mummified and covered with a pearly shroud. More often still, some impurity, a tiny fragment of shell, a grain of sand, which has got there by accident, also finds its way into the forbidden area. Its presence ends in the same way; it too is swallowed up by the pearl and put aside as it were, isolated. This is the usual origin of those protuberances often implanted in the inner face of the valves. From their form and composition they are called "nacreous pearls."

Their size and appearance are subject to variation, but their origin is similar in every case. They are concretions formed around a foreign body, the first centre of a local irritation which has brought about and directed the secretion of the nacreous matter. It is in this way that their fine enveloping layers are produced and deposited, as in the case of the fish's tomb. The story has been generalized and has given up its real secret.

We know the shells which have inside them figurines—tiny figures of chinamen—encrusted in the pearl,

usually little magots, for these pieces come from the Far East. They are pearls formed in a freshwater mussel of the genus *Dipsas*, as a consequence of an artificial stimulation. The producer has chosen a certain number of fine specimens; introduced, between their shell and the mantle, porcelain figurines prepared beforehand; then he has gone away and left to the natural function the job of completing the work. It

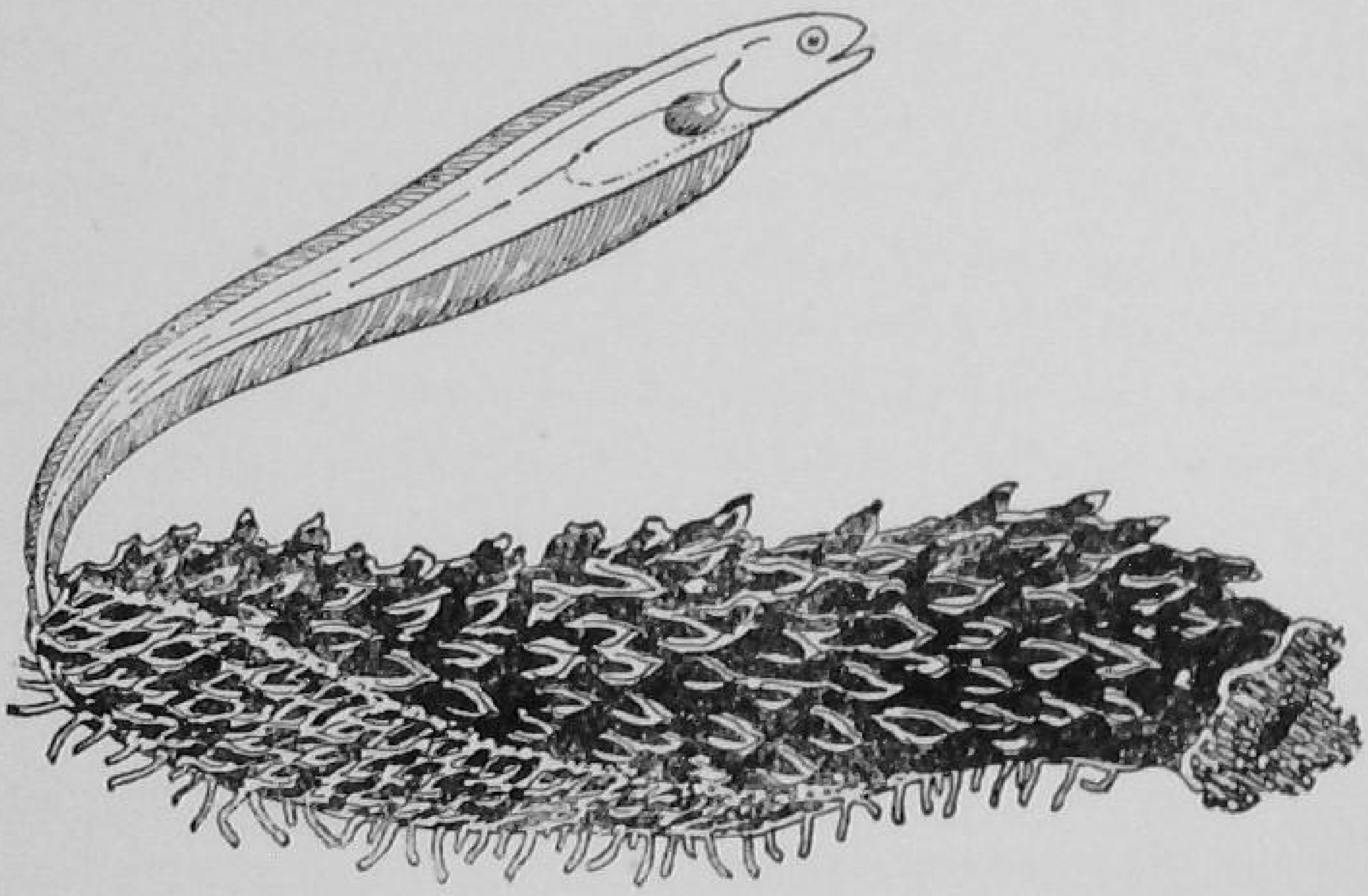

FIG. 52.—Sea-cucumber or Holothurian and *Fierasfer*. The Holothurian, which is black, shows at the right its tentacle-surrounded mouth. At the very left is a *Fierasfer*, introducing itself to the body through the anus. The Holothurian is contracted and shrunken.

has not failed to do its task. When he comes back, he fishes out the shells, empties them, and finds the figurines as he wished to find them, fixed to the valve, immured in mother-of-pearl so fine that all the details of the figurine appear through it. The fish's tomb is here a simple covering, for Nature, not making a distinction, acts in the same way in all cases.

But the story continues beyond the nacreous pearls until we come to fine pearls, to the real pearls. These are much rarer and, instead of being attached to the inside of the valves, occur free in the living tissues like

concretions or cysts, not attached in any way. Hence their regular shape, most often spherical, and the pure smoothness of their surface. They are made of fine concentric layers, and the light, playing in them with more splendour, gives them that peculiar lustre which is the source of their charm and value. But in origin they are not the least different from the others. There is a little kernel at the centre of each, sometimes microscopic, whose presence has set the stimulus at work. After the secretion has been set going, successive enveloping, concentric layers have been deposited and the size of the concretion has increased, until we have a round, regular pearl, with all its charm.

This kernel, the initial cause, is any little thing which has passed through the superficial layer of the tegument and penetrated the living tissues, carrying along with it some elements of the layer, and the pearl is the result. The living tissues have secreted calcareous matter as they always do; then the local irritation has facilitated the formation of the initial cyst; finally, the remainder has been deposited, layer by layer, thickening the envelope thus brought into existence.

This object from which the first impulse comes, varies in different cases. It may originate in the creature itself, some tiny fragment which has accidentally become detached from the outer part of the body, and pushed inside it. It may have been introduced by the hand of man, as in the case of artificial pearls. Most often, it is a tiny creature, a larva of a parasitic worm, which, after attaching itself in the first place to the tegument, perforates it, and passes into the nearby tisues. Then the mollusc reacts in its peculiar way, struggling against the intruder. Most animals, in such circumstances, and when they have the power, make use of their phagocytes, their lymphatic cells, which attack the intruder and gradually destroy it. The mollusc uses a different method. Instead of breaking up and annihilating its enemy piecemeal, it surrounds and immures it. On a

smaller scale, and in another way, it recapitulates the episode of the mummified fish and its tomb, or that of the petrified figurines. In its very flesh, it surrounds the parasite with a layer which cuts it off, thickens it, increases it, continually depositing new layers, and ending by turning into a gem what was originally a tiny coffin.

A Persian poet, attributing a celestial origin to pearls, declared that they were born of dew-drops which fell from the air and were solidified. In his mind, the resemblance, the similitude of flashings and sparkle, justified the attribution of such an origin. In Nature, the reality is deeper and even more poetical. The iridescent pearl, the burial place of an invisible body, brings together in itself the principal aspects of the problems of life and death. It begins by destruction, is followed by an intense degree of vital activity, and ends by creating beauty.

The great collar of pearls, an ornament of high value, with its ropes of glorious gems, is a collection of tiny sepulchres, woven into a splendid set of jewels. Falling over a silken dress, or over beautiful shoulders, its exquisite gleam of pure lustre, at once translucid and brilliant, illuminating things both in appearance and in depth, gives each single gem its true value. Death is a passing accident, a personal affair. Life goes beyond it, utilizes it, employs it for its own purpose, that it may itself continue. The pearl is built around a particle of flesh about to decompose; many a gay insect comes from a chrysalis that developed in foulness and decay; the most glorious flowers bloom beside a tomb; the richest harvest ripens on the battlefield. Life uses everything, even death.

The story of the pearl reminds us of the tomb of pearl. and of the *Fierasfer* which is buried in it. This genus, which contains a fairly large number of species, is found in warm and temperate seas. All its members have the same appearance, the same customs.

They avoid the light, try to find dark corners, bury themselves in the sand or hide in the crevices of rocks, but especially they prefer the shelter of a living body, provided always that they are assured of easy access. There they find the shade of which they are so fond, the protection which defends them, and, in addition, to excite their own vitality, contact with another vitality functioning at full strength. One species found in the Mediterranean exhibits this characteristic in an astonishing degree.

This is the Needle Fierasfer, *Fierasfer acus*. It is small, seldom exceeding five or six inches in length, and, in breadth, only a fraction of an inch. Its long, almost threadlike body, slightly flattened, ends in a short, round head and a pointed tail. Almost all along its length, its belly carries a longitudinal median fin, like a thin, soft blade. Its skin has no scales, and is smooth and occasionally bright. It justifies its generic name Fierasfer, which Cuvier adapted from a Greek word given to objects with a polished surface. It is so transparent that all its main internal organs can be seen. Everything goes to make the creature seem delicate, and this especially in the young, which are practically translucent. They have above them a long nodular filament, spread out like a crest, which later falls off and is not found in the adult.

The American *Fierasfer* sometimes shares the cavity of the mantle of the pearl oyster, but the European species, still more strangely, lives after the same manner in the intestine of the sea cucumber, thus becoming what is practically a parasite. It is, in fact, an intestinal fish, as the tapeworm is an intestinal worm. But there is an important difference; the worm supports itself at the expense of its host, it lives and has its abode in this way; it feeds upon food which it takes from its host, whereas the fish only accepts shelter, for it comes out at intervals to seek food for itself, and then returns to its

accustomed place. Circumstances, that is to say the arrangement of the organs in the sea cucumber, allow of such strange comings and goings, which could not happen anywhere else.

The sea cucumbers are long-bodied Echinoderms, with thick skins, roughened by the possession in their substance of a number of calcareous concretions. They have not carried this to the extent of other Echinoderms, notably the sea-urchin, which has a regular suit of armour surrounding its body. Their genera and species, in considerable numbers, populate the waters of the Mediterranean, where, because of their weight, they live upon the bottom. Some of the sea cucumbers, belonging to the genera *Holothuria* and *Stichopus*, are frequent near the shore, and the fishermen often bring them up, *Holothuria* like large black-puddings, *Stichopus* like broad, thick, pink tongues. Sometimes, some of them contain Fierasfers, especially *Holothuria tubulosa*.

In the sea cucumbers, the digestive tube has two openings, one for each of the extremities of the body, both spacious in the well-developed animal; the mouth, surrounded by a crown of tentacles, the anus, which is bare. The mouth gives access to a long convoluted intestine, which, before it ends in the anus, broadens out into a large rectal swelling. Appended to this enlargement, and opening into it, are two spacious tubular organs which look like hollow, tree-like growths with very thin walls. Because of this appearance they are sometimes called the Holothurian's "lungs," for they are used for breathing. It would be better to call them "gills," since the Holothurians live in water and have to breathe in it. Their method of working can be judged by the mode of their construction. The skin of the Holothurians is not of much use for breathing because it is so thick. So is the intestine, which is filled with sand and little pebbles which the creature swallows on the bottom, leaving to its diges-

tive wall the function of picking out and absorbing the little fragments of food mingled with this debris. The only parts left free are the rectal swelling, with the organs appended to it, and the anus, which is fully open, allowing the outside water free access to the interior. In this way respiration is effected, and the anal orifice adds this new rôle—of breathing and life-giving—to the office it ordinarily performs.

Fierasfer takes advantage of this. Like its fellow of the pearl oysters, it seeks, besides shelter, protection and contact with living flesh, with the currents of fresh water which facilitate its breathing. If it cannot find anything else, it will live in a hole in the rock, a depression in the sand, an empty shell; but here, in this body full of life, it exalts its own life, and takes full advantage of all the well-being it is capable of experiencing. It settles down in the spacious rectal cavity, curls up there, and so sheltered, takes the fullest advantage of the dwelling to which it has invited itself, and to which its host has welcomed it.

This is a strange enough affair in itself, but less so than the manner in which the agreement is compounded. These Holothurians, in spite of their apparent torpor and inertia, are sensitive, ticklish, and easily upset, and they show this in an alarming manner, breaking off and ejecting their whole intestine when picked up. The lodger must exercise extreme prudence and make his contact with the utmost care, if he is to avoid such consequences. Yet there is no difficulty in coming to an arrangement. The fish approaches when the anus opens completely and remains wide open. It begins by introducing its small pointed tail into the orifice; then, quickly but softly, slipping in backwards, it takes in the rest of its body, including the head, until, finally, it disappears entirely. It is so delicate in its movements and gets on so well with its host that the latter, apparently without raising any objection, sometimes allows its guest, now become its lodger, to put its head out by the

opening and survey the neighbourhood, to go out and draw back as it would from a hole with inert walls. Having given its guest permission to lodge there, having allowed it to take up all the room it needs, it continues to permit it to make itself at home, like a good landlord, with the extraordinary peculiarity that the lodging itself, situated in the very body of the landlord, is in the rectum. Nature often surprises us by its arrangements, but it would be difficult to discover a device more astonishing than this particular one.

We may regard it with astonishment, and indeed so we should, but we ought further to consider it in its true light, and see what it actually implies. It is eminently significant, and as full of suggestion as may be. It marks a definite level from which we may measure others. If it were anything less, we might see in it nothing but an ordinary association, such as we find in those species of fish which frequently shelter themselves beneath a piece of floating wreckage or under the parasol-shaped body of a jelly-fish. If it were anything more, it would take advantage of the situation to feed the guest at the expense of the host, and become a complete parasite, like the intestinal worm. But in its case, we have something betwixt and between, and when we put it in its proper place in the series which begins with the pearl oyster, it helps us to see things as a whole.

Nature, in its immensity and diversity, rearing its individuals in the mass, distributes to all the means to live. In the first place, it procures these means of itself; but, more than this, it brings together as best it can those creatures to which it gives life, and makes them help one another; it compels them to aid one another. If, sometimes, the form this assistance takes surprises us, its significance is the one thing to bear in mind. Nature makes use of everything that it contains. It uses the flesh of one to form that of another; it makes use of death itself to take this maintenance to its ultimate limit; it brings life itself to contribute to the better

securing of its action. The whole is one vast symbiosis. Living Nature constrains its creatures to observe that mutual help which it institutes without respite, to adapt themselves to the regulating laws which enable it to establish that mutual aid. Its tireless, never-ceasing labours proceed always according to a governed plan.

CHAPTER XIX

THE CARP AND THE STICKLEBACK IN THE OLD POND

I LIKE the melancholy air that pervades an abandoned stretch of water. Nobody goes there; nobody bothers about the place. Only the children sometimes come to play on its shores. Walkers avoid such places. They are given striking names: the Fairies' Pool, the Witch's Cauldron, and the like. Tragic legends are related about them, stories of fights, of murder and drowning. It is said that their quiet waters cover buried houses and palaces, and, in actual fact, some of them are the great moats of fortified buildings whose ruins may occasionally be seen not far away. Others are hollows formed by an accidental sinking of the ground, or ponds once created by the hand of man, which have gradually come to be disused. Their banks, covered with moss and brushwood, are sometimes beautified by fine large trees with glorious foliage, which stretch over them their branches as if to cover and protect them. Tufts of reeds, little green islets, emerge in one place and another. An abundant vegetation rises from the bottom to the surface and forms broad stretches of dark green. The light is soft and even, pierced here and there by the golden shafts of a sunbeam striking each separate object. The wind, tempered by the surrounding woods, does not cause a single ripple. Everything is calm and still.

So, on a burning summer's day, I find it pleasant to sit down under the canopy of trees, and in that light and shade delicately sketched by the green of the leaves and their reflection on the water, to enjoy the delicious coolness which one finds only in such a place. In the neighbouring countryside everything is asleep, overcome by

the scorching heat of the sun. Here, beside the old pool where it is shady and cool, everything thrills with an intense but sober animation, tempered by the frame of green. This restful refuge is a little world populated by many tiny creatures. Birds which I cannot see sing merrily in the trees. The sound of dry leaves being brushed aside, now and then, marks the passing of a young rabbit. Flies buzz as they come and go. Thin swarms of midges dance whirling through the sunbeams. Dragon-flies in emerald armour sail by on their large transparent wings. Sometimes a kingfisher, swooping down, flashes before my eyes like a sapphire arrow. And if I look into the moss about me, I see many tiny insects, busy moving up and down the minute blades. When I lean over the water and look into its depths, there too I see a profusion of life, a swarming of different living beings. An untiring vital animation is hidden beneath the appearance of perfect rest, and myriads of tiny existences are being lived, born, maintained, until they disappear without disturbing or changing the appearance of the pond which gives them all shelter.

As we watch them side by side, in the water and in the air, examining and following first one and then the other, time passes quickly. And not only does the time pass, but any notion of its meaning, of what it is, grows less and almost disappears. A few minutes, or rather a few of those periods which we call minutes, which mean so little to us, are enough for several of these little lives to accomplish their circle almost completely. In a few hours, an insect comes out of its chrysalis, flies away on its wings, reproduces itself, and dies. In a few days, a few weeks at the outside, whole generations are swept away and replaced by others which will be replaced in their turn. Our measure of time, created in our own fashion and based on our sensations, ceases to have exactness and rigidity. When we realize how these generations uninterruptedly succeed one another, we

feel ourselves floating above duration, and assisting at the succession of things. We see connections and relations between things we are accustomed to distinguish and separate. Beyond the individual which perishes, we see its ancestry and its succession. Consciousness develops further. In relation to these lives, it becomes what for a generation like our own would be that of a being who, living for thousands of years, should see before him the torrent of peoples and generations.

There are fish in the pond. I see them every now and again passing below me among the submerged plants. Most of them belong to the small species, like loach, and a few roach. But there are more sticklebacks than anything else, and they abound in several places. And there are bigger creatures. From the line I have thrown out, I get large eels, keen hunters of tadpoles and frogs, whose numbers they keep down. There are a few large carp too, but they do not often allow themselves to be caught. Sometimes I hear one as it comes up to the surface; the noise made when it breathes a mouthful of air strikes the ear and attracts my glance. I see a large snout, but it soon disappears; the carp has dived back to its lair among the reeds, leaving no trace but a series of broad circling ripples, where it showed itself. The carp are distrustful, wild, different from their fellows in the lakes of a park which has many visitors. These make a business of coming to the shore to gather the bread which is thrown to them.

Yet I once had the opportunity to examine one of them as well as I could desire. I heard a splash such as one usually hears when the fish drops back into the water, but it was some way off, and I got up to go towards the sound. To my surprise the noise, instead of ceasing, continued. When I got near enough, I discovered the reason. The carp was struggling on the surface of the water; escaping doubtless from some enemy, an otter perhaps or a water-snake, which had

been after it; it had become caught in a thick tuft of reeds and could not get free. Three-quarters out of the water, its boundings and somersaults brought it out more and more until it was completely above the surface. Its great mouth opened and closed; it breathed in air and blew it out again; its gill-covers beat vigorously; its tail kept striking and bending the stalks of the reeds. These efforts were in vain; the creature, imprisoned, caged, caught in this natural trap, was gradually stifling. I went to get help. With a hook, we took it, brought it to the bank, and there, at last, it died.

Then I could contemplate this giant of the pond, hitherto unseen, but now spread out before its captors, who were looking at it with curiosity. It was measured; the total length from the tip of the snout to the fork of the tail was nearly three feet. It was weighed, and its weight came to slightly over thirty-four pounds. Everything about it, not only its size, denoted old age. The large snout had thick lips and barbs which were partly broken. One of its eyes, which had obviously been damaged a long time before and was almost empty, was covered with a whitish, chalky film. The long dorsal and anal fins which had beaten the reeds had been torn, several of their rays were bared and broken. Many of its scales had come away, leaving the skin bare and raw in places; others which were still in place were broken at the edges. The intestine, which we opened to its full extent, had in it only a small quantity of semi-liquid matter, as if old age had arrested the capacity to take solid food.

"It must be very old," one of the bystanders remarked. "It is as decrepit as a centenarian. Is it possible to tell how old it is?" I answered this question in the only possible way. I took from my pocket the little magnifying glass which as a naturalist I always carry about with me, and from the carp's body, not far from the dorsal fin, I took one of the best preserved scales, wiped it with my handkerchief to clean it, and then

looked through it against the light to see how many bands of annual growth there were. The examination did not give any definite result. I could see, about the middle of the scale, four bands corresponding to the first four years of the creature's life in its youth, but, towards the edge, the bands became narrower, interrupted one another and joined up, not providing any means by which I could form an opinion. The mystery of this fish's life continued after its death.

But if, in this particular instance, where certain proofs were missing, the mystery continued, it was different in other cases. We know the places where the old carp live; we know, if not exactly, at least with a certain degree of probability, how long they can live, judging by the time when they were put into the water still quite small. It is sometimes said that they may live to be a hundred, even two hundred or more years old. But people forget that the waters have been restocked at different dates to make up for losses. Putting aside fairy tales and exaggerations, we may reasonably give the very large carp several decades, though it is not safe to go too far, to go beyond half a century to a hundred; the strength of the specimen and circumstances being the main factors to take into consideration.

In this capacity for longevity, two important facts stand out above the rest. The first is the growth itself and the great size to which it may attain. We often look upon things with the eyes of custom and regard the carp as a small or middle-sized fish, and leave it at that. The real facts are different. The carp usually eaten are young ones, like veal or lamb; they have hardly begun to grow and are still far from their end. The individual left to itself would continue to grow and get bigger for many years to come. The adult, like the sheep or heifer, is a creature tolerably large in size and quite heavy. When one is met with, it is considered monstrous, unusual, and astonishing; as a matter of fact, it is perfectly normal.

The second fact is concerned with the manner of this growth, its swift beginning and its ultimate slowing down. This is easily observed when the carp are raised in ponds, whose owners, picking out the best specimens, select them as breeders. In many of them it is not uncommon to see females kept for breeding whose age amounts to as much as ten, twelve, or even fifteen years. Their size and weight come somewhere near that of the "monster" caught in the old pond; they weigh from twenty-four to thirty pounds, and measure from twenty-five to thirty-two inches in length. Thereafter, the stage of old age sets in. Kept for the sake of their eggs, which are both larger and more numerous, almost reaching the million figure in the case of the finest specimens, the carp then become senile and gradually lose their fecundating power. But when circumstances are propitious they may still go on living. They seem to become decrepit somewhere between the fifteenth and twentieth years. Upon land, a creature so stricken would soon die. But in the water, which supports and maintains it, it may last longer, longer even than it had lived before. This period of decrepitude, which is necessarily short in the case of land animals, is prolonged in the water animals, and may even be accompanied by a continuance of growth, although at a slower rate, and end by producing creatures which surprise us, not only by their general appearance, but by their possibly great age and the hugeness of their dimensions.

This longevity leads to new consequences. Growth, not being concerned with the development of the body alone, is further concerned with reproduction. Every spring, the carp begin to spawn. The females in ponds devoted to carp breeding begin in their fourth year, and afterwards, each spring, they spawn again, only more abundantly each successive year until the beginning of the period of decline and old age. In the course of its existence, the creature reproduces itself several times

and at regular intervals. As it grows, it engenders fresh generations, which will follow its lead, provided circumstances are favourable, and produce new generations which in turn will grow and propagate. It thus gives a greater intensity to its personal life, and magnifies its scope by passing it on to the many offspring which it produces. The carp's life is made up of many successive episodes, and may truly be described as a well-filled one.

The day after my capture, when I looked once more upon my old pond and thought over the varied incidents of the other lives lived in its waters, and listened to see if I could hear more of the noises made by large carp in difficulties, I meditated upon this longevity, this faculty of growth, and this power of reproduction. And I leaned over the edge, to see in the depth of the water creatures more minute, more fragile, which had none of these qualities. Their destiny seems so different, so stricken by weakness and lack of capacity. Soon I noticed a few sticklebacks out hunting, and the contrast between their lives and that of the carp became startling, although the same pond holds them all, affords them all a livelihood, and gives them all the same protection.

The differences are manifest. The carp is large and placid, the stickleback small, slim, turbulent and fidgety. It is a great hunter, always busy pursuing prey smaller than itself, especially the young of other species. On a smaller scale, it carries out within a less extended field of action the habits of the pike among the larger species, or of the shark in the sea. It is very voracious and destroys *en masse*. In spite of its relative minuteness, it often becomes a scourge to all its neighbours, even the strongest of them, so many of their eggs and their young does it devour. Aggressive, pugnacious, well armed both for attack and defence, it goes through the water like a flash of silver and pounces upon everything which seems to it an easy prey.

I sometimes catch sticklebacks with a well-baited

bottle trap, although their distrust and swiftness often enable them to escape it. If I take one and examine it closely, I find a small-sized fish, for the largest seldom reach more than three inches in length, oval and regular in shape, and remarkable for the strong pointed spines with which various parts of its body are armed. Under the belly, not far from the head, in the place of the pelvic fins I find two strong movable spines, tiny daggers which I can move by pressing the tip of my finger against the point. These the creature itself can move. On the back, almost opposite, are three other spikes which stand upright, two of them being larger and stronger than the third. With this armament, the tiny fish, in its own small world, plays the part of a bandit always spoiling for a fight. It will go into the hollow of my hand; it hardly weighs anything at all, so small is it, yet if I close my fingers over it, I feel the points of its spikes go through my skin and prick me. It is for this reason that it has gained its name stickleback. Other countries and various districts have given it other names, but always based on this characteristic. Its scientific name, *Gasterosteus aculeatus*, is inspired by the same idea.

This armament is not limited to the daggers on the belly and back; it is not confined to these offensive weapons. It also includes a coat of mail made of broad plates arranged in a row, covering both sides. But this defensive armour is not always present; when it does exist it varies in size; sometimes it covers the whole side, sometimes it protects only a part of it. This diversity indicates that, in spite of its appearance, it plays a small part in the creature's life. Usually, the stickleback makes use of its swiftness and its offensive outfit. These are enough to enable it to avoid its enemies, to defend itself against them when necessary, and to pounce upon the prey on which it feeds. Beside a carp it looks like a dwarf beside a giant; yet both, in spite of this difference in size, live together and flourish, big and little alike. Nature protects them both in the same way,

showing that, with her, differences of size have neither importance nor weight.

But this contrast is not the only one; it is even the least. That which concerns capacity for spawning is more considerable. A spawning carp produces, in the spring, as many times 100,000 eggs, on an average, as it weighs kilograms; a female weighing sixteen pounds lays almost 800,000 eggs. This figure being proportionate to its size, so much could not be expected from the tiny stickleback. But the stickleback exaggerates the possible diminution, its normal spawning is extraordinarily limited. Usually the female produces only two or three hundred eggs; it is one of the least productive of all fishes. But there is a certain improvement in the size of these eggs, which are a little larger than those of the carp and have a diameter of from one and a half to two millimetres. But this smallness of numbers, not to speak of size, has no influence on vitality. The balance of correlation between species which Nature has established does not give the carp a predominance in numbers ever the stickleback in proportion to the eggs spawned. The wastage during the early period of growth soon gives the stickleback an advantage which it would otherwise lack, and the sticklebacks themselves contribute to this by destroying the recently hatched young carp around them.

So, in practice, the differences become less noticeable and the contrasts less marked. The differences do not seem so striking or so persistent as they did at first, when we consider creatures in space alone and such as they appear at a given moment. Time has its part to play in the manifestations of life. It assembles and coordinates what forms and attitudes distinguish and differentiate; it tempers divergences and reconciles the irreconcilable. Its power gives real meaning to life considered as a whole.

The contrast between carp and stickleback in spawning is not limited to the number of eggs produced. It

goes deeper into the real depth of the creature, and is concerned with the number of spawnings in the same individual, and, by extension, to the length of its life. Unlike the carp, which spawns regularly once every year for several consecutive years, the stickleback spawns only once, or at most twice, in all its life. This spawning takes place, according to locality or climatic conditions, in the latter part of spring or the beginning of summer. Usually, when it is accomplished, it exhausts the reproductive capacity of the creature; it does not happen again, at least in the majority of instances, and does not recur the following spring. And there is a very definite reason for this, which is that the completion of the reproductive act marks the approaching end, the disappearance of the individual.

It is easy to see this when we fish for stickleback at regular intervals throughout the course of the year. At the beginning of spring, before the spawning, when the water, newly warmed by the sun, indicates the end of the winter's rest, all the sticklebacks we catch are of average length or large size; all, or practically all, are obviously adult and perfect animals. This is the case also at the spawning period, but not afterwards. During the latter part of summer, the fish we catch are a mixture of large and very small sticklebacks, the latter newly hatched from the eggs that have just been spawned, the former the adults which produced them. Then, towards the end of summer, when autumn announces itself by the first spells of cold weather, we find the larger fish disappearing and a greater number of small ones. When we compare the results obtained, we find increasing development on the one hand, and decadence on the other. Finally, as winter sets in, the large sticklebacks, except for a few survivors, have ceased to exist; whereas the little ones, having passed through the stage of youth, have become those we shall catch the following spring, all ready to spawn when the weather begins to get warm.

This is a general view, the details of which may be filled in by multiplying the number of investigations, taking into account a greater number of individuals, and drawing out curves to show the position. But the conclusion is that the stickleback, spawned in the spring of any particular year, accomplishes its main growth during the course of that year, gets over the winter, reaches the spring of the following year, then reproduces itself, when it is only one year old, lives on through the following summer and dies during the autumn, or at the beginning of winter. Its whole existence, from one spring to the beginning of the following year's winter, lasts, on an average, eighteen months, two summers separated by a single winter. When this time is over its life is ended, death is unescapable. And this year and a half has only two phases, two moments of real fullness of life, the two summers, winter being a period of rest. The complete chronological age is eighteen months, but the epidosic age, which is given up to the real life and the growth of the individual, is hardly more than twelve months. That is all, in time, that the life of this little, agile, brilliant creature amounts to.

Here we see the contrast with the carp at its greatest. Not only are the two fish dissimilar as regards size, number of spawnings, and the quantity of eggs spawned at one time, but they differ also as regards length of existence, the extension of their life in time. One reaches its ultimate size a year after it is spawned, then spawns itself, ceases to grow, and quickly perishes. The other lives on after its first year, continues to grow, reaches considerable size and, each year, fulfils its work of reproduction. The contrast is striking. The large carp enjoys privileges which are denied to the stickleback. Science is coming to the conclusion that these differences in the manifestations of life perhaps result from differences in the internal secretions of the organism. We observe that living Nature introduces a degree of inequality among creatures,

that it favours some and does not favour others, that it gives the former the means to live longer and fill a higher position in the scheme of things, whereas it denies the same advantages to the latter, keeping them small in size, and soon bringing them to an end. To us these differences may seem unfair; for why should this be the case, and what reason can there be for behaving so unequally? The question goes beyond the carp and the stickleback; it arises in respect of all the living world, in which big and little elbow one another, ceaselessly, without ever stopping.

It is not difficult to find the answer. Our old pond, by the constancy of its population, itself provides one. We need only enlarge it and apply it to Nature as a whole; the significance remains. The sticklebacks may disappear every year; the pond still contains them, for those which die are replaced by those which are born, and their generations succeed one another without fail. If the pond, several centuries old, could give an account of itself, it would tell us that it gives to individuals which are perishable only a passing consideration; that it devotes its main attention to keeping up a succession of these individuals in time, keeping up and maintaining intact the series of their successive generations. It sees them all pass one after another, and devotes itself to providing what is necessary to preserve the succession, this being its main and preponderant object; as, in a carefully constructed piece of work made up of many tiny consecutive details, we see them all as a whole and so the way in which it is made.

And this is the case with Nature as a whole. Life fashions the individuals, devotes a moment to their upbringing, gives them the necessary capacity for action; but, above all, is concerned with the succession of its creatures; the succession of their generation in time, and this is its main work, judging by the care it takes to make sure of it. What does it matter to this long series of generations, chained one to another in the course of

time, whether it is assured several times or once for all, by individuals whose business for the moment it is to act as reproducers? What do differences of size and length of existence matter? What do these inequalities really amount to, and what is their weight in the scales in which all things have been weighed since the beginning of the ages? To tell the truth, they amount to so little that we may think they hardly count, that they do not exist. They seem striking to us, because we judge them by our own measure, by our own existence during the brief moment of time allotted to us, but in Nature, perfect and complete, replacing one another along the immensity of time, it is as though they never existed. Individuals, actors on a fleeting stage, only count as items in the series of succession of which they are a part; and the Fates, the daughters of destiny, take them all in turn as tiny threads in the web they are continually weaving.

Every individual, every creature animated by life, is only a momentary, transitory figure. He succeeds his ancestors who have disappeared; and he precedes the descendants who will take his place. For the duration of his existence he is real, for he is distinguished from what surrounds him, but he only partially possesses reality, and then only in space, in relation to what is not himself. As soon as he is considered in time, the reality of autonomy disappears and breaks up. At his first beginning, he consists of a germ which, forming a part of the body of his producer, has not yet acquired the independence with which it will later be endowed. In his maturity, he separates from himself the germs which he engenders, portions of himself which will serve to fashion those who will come after him. After his death, his flesh decomposes and its elements are dispersed through the inanimate world, mingling with those already there. From beginning to end, he never has complete possession of himself. Real in space, he becomes, in some way, fictitious in time, for his individu-

ality then ceases to exist. He is a link in the continual chain of the line of generations from which he depends. When his time comes he presents himself, takes his place as he must, then yields it up, and the web goes on being woven as long as is possible without breaking. The Ego is only a metaphysical abstraction created by our mind; in Nature, real and complete, the Ego has no existence.

In this way, individuals show what they amount to in the whole of living Nature, and they do not amount to very much. When we see them gathered in the world, peopling the air and the waters, considering them in the environments with which they fill up space, we are inclined to envisage them as alone, and thought generally stops there and goes no farther. But if, yielding to the very condition of life which animates and maintains its creatures in time and space alike, the mind evokes the successive spectacles of Nature according to their appearance and their replacement, it must give to time and the succession which it brings into being, the preponderance which is their due. Individuals assume their proper rank as temporary links in the chain of their generations. And their dissemblances, their inequalities, the astounding diversity of their forms and functions, seem less strongly contrasted and combine to give to each the place it can fill.

If individuals, the visible factors in the spectacle of Nature, lose thereby a part of their apparent importance, the lineage, on the other hand, the succession of individuals issuing one from the other in the course of time, acquires an importance which is so much the greater as it shows itself less. Our sensations are hardly aware of them; they only see the points of the web. Only our intellect can reconstruct them, and give them their proper place, which is the first place. They are fictitious in relation to our senses, for the senses can only appreciate things in space and for short moments, but they recover their fundamental reality through reason, which

reconstructs the web as a whole, summoning all its means of knowledge for the purpose.

Living Nature in its totality is made up of series of generations which have succeeded and replaced one another in time since the beginning of the ages, distributing their individuals all over the globe in space. The globe and space are small; time, on the other hand, is immeasurable, accumulating centuries by millions from the beginning, piling up passing generations in still more considerable quantities, allowing individuals to multiply abundantly as they succeed one another. "Nature is Time," Lacépède writes, inspired by Buffon his friend and master. A striking formula, which fairly expresses the full reality.

Life, thus evoked, takes on a greater value, much greater than that commonly accorded it. It is no longer simply a limited animation, which stops and is done after having supported one individual during his brief existence. It is more, and better, than a collection of forces opposing themselves to death. It is much more, for it goes beyond death and the disappearance of the individual. The animation it bestows extends to entire lineages; it does not cease, it does not fail. For it, death simply does not exist; individuals fall out, but it continues. Those to whom it attaches itself it raises one after the other, then lets fall again, but, as it does so, it unceasingly takes up new objects and animates them in turn. It is spirit; it is the will of energy expressing itself in time, applying its power in fashioning the moving and changing figures of the creatures it activates. Emanation of the creative Power, it ensures the everlasting duration of creation.

In this uninterrupted chain of existences, the individual in his turn assumes an importance greater than it appears to possess. The little stickleback in its short life, the fifty-year-old carp, and every creature considered in itself, are not sensitive automatons, placed by their structure under the control of their environments,

and destined to perish when they have lived. This personal life, which today supports them, is a fragment of the general life, of activity expended in the course of time. It is the greater for this superiority; it is its representative for a moment before it passes it on to others. Real, complete life is a perpetual becoming, in which each, according to his place in the scheme of things, has his part.

Old things, which have seen the waves of hastening generations pass by them, have their lesson for us. They remind us that what we see before us now is not all there is to see, that it succeeds many other sights and will itself be replaced by others again. They make clear to us what time really is in living Nature, not a fugitive moment, but a vast duration, and what a part it plays in the animation of life: the main conductor, the director of events.

The old pond counsels us to meditation and recollection. It appeases and consoles us; it assumes the rôle of a benevolent personality. Its silence, its repose, its shade, cut us off from the bustle of the outer world, and allow thought to have a chance, to remember better, to appreciate values more truly. Left always to itself, it is still what it was when I first halted on its banks. It teaches continuity and perenniality. Before me, it is the same calm, green water, traversed by the swift journeyings of little fishes, the same foliage, the same soft noises of insects and birds. Nothing seems to have moved.

The frame has remained: the view has not changed. But the creatures which occupy the stage have changed. Though they are not the same as those of other days, they are like them; they replace them exactly, for generation has succeeded to generation. The play produced by life has remained what it was. The actors have disappeared one after another, but before they left the stage they handed down from parents to descendants, from generation to generation, the

costumes they should wear, and the parts they should play.

The things of Nature have a genius of their own, a deep, interior meaning. If it is no longer represented in the mythical form of a pagan divinity, or of a magician able to appear and disappear at will, or of a necromancer, it is there none the less, and appears of itself alone in their appearance and in their harmony. Thought gazes, listens in itself, sees, and understands. It divines that life in the creatures that perish, through their appearances and their transformations, keeps constantly about the work it has undertaken since its beginning. It prolongs its labours, accomplishes them without stopping. So everything that exists, holding within itself a lasting part handed down from flesh to flesh, can, according to its means, despite inequalities and contrasts, have its share in the general effort.

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